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SOME PROBLEMS IN STELLAR PHOTOMETRY

By Joel Stebbins

ASTRONOMICAL OBSERVATORY, UNIVERSITY OF ILLINOIS

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It is the purpose of this note to point out some of the researches which have been made possible by the development of the selenium and photo-electric photometers. The first advantage of these electrical devices is a considerable increase in accuracy over what is possible by visual and photographic methods. Perhaps the best field for immediate investigation lies in the study of the eclipsing variables, which give us the only direct clue to the actual diameters of stars. Nearly one hundred of these systems are now known, and new ones are continually being found. In the various studies which have been made, there is one line of reasoning which seems to have been overlooked, as follows.

Among the systems discovered, some are constant in light for a large fraction of the period, while others have relatively long times of variation, and are thus easier of discovery and observation. If P be the total period, and D the time of duration of the eclipse, the probability that a star will be faint when observed at any time is D/P. It seems plausible to assume that if we take the number of discovered stars of each class and multiply by P/D we shall get numbers representing the relative occurrence of such objects which are actually visible and might be discovered. For example: suppose that in a random search about the sky we find 5 stars where the eclipse is $\frac{1}{5}$, and 5 where the eclipse is $\frac{1}{10}$ of the period. Then instead of the relative numbers awaiting discovery being equal, it seems much more probable that there are about 25 of the first class to 50 of the second.

There is another consideration that for every double system which exhibits eclipses in our direction, there are others whose orbit planes are inclined so that we miss the eclipse altogether. We may adopt half a

stellar magnitude as the ordinary limit above which a star must vary in order to be detected, and if i represents the corresponding inclination the probability of an eclipse of this or greater amount is given by cos i. Conversely, if we have found a certain number of stars with a given type of eclipse, we may multiply by sec i and obtain the corresponding number of such systems with orbit planes in all directions.

Therefore, if we separate the known eclipsing systems into classes according to the ratio P/D and multiply the number in each class by P sec i/D, we get numbers which represent the frequency of occurrence in space of the corresponding systems. From data already brought together by Shapley (*Contributions from the Princeton University Observatory*, No. 3, 82, 1915), the tabulated results have been found. The third line has been derived from the second by the proper multiplication as described, the products being reduced in proportion to make the total of 88.

Value of P/D	2–4	5–7	8–10	11–13	14–16	17–19	20–22
Number of stars observed	12	41	23	7	4	0	1
Relative number existing	3	24	26	16	13	0	6

The interpretation of these results is that there are relatively few systems with components nearly in contact, $P/D = 2$, and there is a distinct preponderance of P/D from 5 to 10, with maximum say at 8. This corresponds to a distance between centers of about 5 times the average radius of the two bodies.

With more data we could derive similar results for each of the spectral classes. The systems with spectra of classes G and K seem to be quite different from the others, and omitting these we find for stars of B, A, and F spectra a close connection between the relative length of eclipses and the average periods.

Value of P/D	2–4	5–7	8–10	11–13	14–20
Number of stars	9	38	22	6	4
Average period, days	1.0	2.4	5.0	11	15

The increase of period with increasing P/D seems to mean, what has been pointed out before, that the stars which are farther apart move more slowly not only on account of the greater distance, but also because these systems are less dense. However, as the density seems to be a marked function of the spectral class, a further discussion with more material is essential.

From these and other simple considerations, we may conclude: *The preponderant type of close binary with components of the same order of size and of equal or unequal brightness, consists of bodies whose distance*

between centers is approximately 5 times their average radius, whose period of revolution is about 4 days, and whose mean density is 1/20 that of the sun. Systems of greater or less separation are not so numerous, or we should find more of them among the eclipsing variables.

The foregoing discussion is based upon the variables which have been found by visual and photographic methods, but there is abundant field for work in the same lines for the new forms of photometer. Here instead of examining thousands of stars and picking up a variable now and then, it will be better to make a special study of a few stars which from spectroscopic results are known to have large companions. I have made a start in this testing of spectroscopic binaries, and the first two stars observed were found to be variables. Further observations yielded 4 variables out of 11 stars, and among the hundreds of spectroscopic binaries already known, there are no doubt dozens of variables awaiting discovery. The point to emphasize is that not only will systematic studies of stars which vary in light give us direct information, but indirectly we can draw far reaching conclusions about stars which do not vary.

In addition to the eclipses, other causes of light-variation of binaries may be mentioned, such as ellipsoidal figure, orbital eccentricity producing changes in the interaction of radiation of the components, tidal phenomena, and the effects of resisting media. There is a class of objects like *Polaris*, whose spectral variations are accompanied by synchronous light changes, but there is the possibility that these are not double systems. Some day we shall probably be able to assert that all stars with rapid changes in their spectra, whether these be in the shift or the character of the lines, must vary in light, and it will become a practical problem to find really constant stars to be used as standards of comparison. These may be found only by trial, and we shall have to observe stars in groups so as to eliminate the variables. No doubt we shall find a difference in the average amount of variation as we pass along the spectral series.

This takes us to the case of our sun, which, according to Abbot, is a variable star. Of the variation there can not be the slightest doubt, for a single sunspot is enough to change the total light, the only question is how much. In direct measures of the sun's radiation, the chief difficulty lies in the proper allowance for the atmospheric absorption, but this trouble may be eliminated by comparing the reflected light of one of the planets with the light of a number of stars. Probably *Saturn* is a good object for this purpose, as there are few markings on the surface, but *Uranus* would be still better on account of its slower motion,

and the greater number of suitable comparison stars which could be found for it.

Another advantage of the selenium and photo-electric methods comes from the fact that the light of a body like a comet, nebula, or star cluster may be compared directly with a point source like a star. In addition to photometric studies of diffuse objects, it is not too much to expect that we shall be able to get a very good measure of the general light of the sky, i.e., measures of the total light of the stars both in and out of the Milky Way.

The photometry of lunar and solar eclipses also presents problems which can be attacked with success. The total light of the corona as well as its distribution will be easy to determine. Measures of the zodiacal light can be made, and also any absorption of star light by these particles near the sun may be detected. This last would require very accurate observations, but would be feasible at a mountain station.

The problems here presented are some of those for which we already have the means of attack, and which will lead to definite results. Besides what may be predicted in a way there is always the probability of something unexpected, and it is evident that only a beginning has been made in the use of the new methods.

THE COMPOSITION OF BRACHIOPOD SHELLS

By F. W. Clarke and W. C. Wheeler

UNITED STATES GEOLOGICAL SURVEY, WASHINGTON

Presented to the Academy, April 8, 1915

The present communication[1] is part of a much larger research relative to the inorganic constituents of marine invertebrates. The object of the investigation is to determine, more definitely than has been done hitherto, just what substances are contributed by each group of organisms to the marine sediments, and therefore to the formation of marine limestones, with especial reference to their magnesian and phosphatic varieties. A few analyses of brachipod shells are already on record; and they show that they fall into two chemically distinct groups—one calcareous, the other highly phosphatic. This conclusion is supported and emphasized by the new data obtained by us, which, however, bring out some minor peculiarities that seem not to have been previously observed. For our material we are indebted to the kindness of Dr. W. H. Dall, who selected typical specimens from among the duplicates in the collection of the U. S. National Museum. First in order come five brachio-

pods representing as many genera in the calcareous group. The species analysed are as follows:

1. *Terebratula cubensis*, Pourtalés. Coast of Florida.
2. *Terebratulina septentrionalis*, Gray. Eastport, Maine.
3. *Laqueus californicus*, Koch. Esteros Bay, California.
4. *Rhynchonella psittacea*, Gmelin. Shetland Islands.
5. *Crania anomala*, Müller. Coast of Norway.

Actual analyses

	1	2	3	4	5
SiO_2	0.06	0.50	0.18	0.14	0.21
$(Al, Fe)_2O_3$	0.04	0.14	0.47	0.23	0.26
MgO	0.44	0.62	0.32	0.23	3.90
CaO	54.96	51.79	54.48	53.76	48.67
SO_3	0.21	0.66	0.21	0.31	0.97
P_2O_5	trace	trace	trace	0.17	0.25
Loss on ignition	44.35	45.28	44.46	44.81	45.38
	100.06	98.99	100.12	99.65	99.64
CO_2 calculated	43.42	40.55	42.91	42.16	40.88
Organic matter*	0.93	4.73	1.55	2.65	3.52

* Approximate. Loss on ignition minus CO_2.

Rejecting organic matter and recalculating to 100%, the analyses assume the following rational form.

Revised analyses

	1	2	3	4	5
SiO_2	0.06	0.52	0.18	0.15	0.22
$(Al, Fe)_2O_3$	0.04	0.15	0.48	0.23	0.27
$MgCO_3$	0.93	1.37	0.68	0.49	8.63
$CaCO_3$	98.61	96.78	98.30	98.20	88.59
$CaSO_4$	0.36	1.18	0.36	0.55	1.72
$Ca_3P_2O_8$	trace	trace	trace	0.38	0.57
	100.00	100.00	100.00	100.00	100.00

For comparison, the analyses of the following calcareous brachiopods, made elsewhere, are significant:

6. *Terebratula* sp. Collected by Pourtalés between Florida and Cuba. S. P. Sharples analyst.[2]

7. *Terebratulina caput serpentis*. Locality not given. F. Kunckell analyst.[3]

8. *Crania anomala*, Müller. Locality not given. Kunckell, analyst.

9. *Waldheimia cranium*, Müller. Locality not given. Kunckell, analyst.

10. *Waldheimia cranium*, Müller. Collected by Norwegian North Sea Expedition, Station 255, latitude 68°.12′ N., longitude 15°.40′ E., in 624 metres depth, and at bottom temperature 6°.5 C.

11. *Waldheimia cranium*. Lofoten Islands. Analyses 10, 11, by L. Schmelck.[4]

Older analyses of calcareous brachiopods

	6	7	8	9	10	11
SiO_2	....	....	....	....	0.60	?
Fe_2O_3	trace	....	....	....	0.40	0.15
$MgCO_3$	trace	1.05	3.40	....	1.20	1.40
$CaCO_3$	98.39	94.60	87.80	96.20	96.20	95.58
$CaSO_4$	....	2.40	2.15	0.90	0.85	?
$Ca_3P_2O_8$	0.61	....	0.28	0.18	....	....
SrO	....	....	....	....	....	trace
CaO	....	....	....	0.30	....	....
MgO	....	....	1.80	0.60	....	....
P_2O_5	....	....	....	....	trace	0.12
Organic matter	1.00	2.55	4.30	2.00	1.24	1.99
	100.00	100.60	99.73	100.18	100.49	99.64

With these analyses ours agree in a broad, general way, although the older ones vary much as regards completeness. Kunckell's analyses, showing free lime and magnesia are suspicious, but only in this detail; otherwise they have confirmatory value. All the analyses show that this group of brachiopods have shells in which calcium carbonate is the principal constituent, and the proportion of organic matter is low. The only aberrant one is *Crania*, which is noteworthy on account of its high percentage of magnesia; in which respect if recalculated to a common basis, Kunckell's analysis agrees approximately with ours. *Rhynchonella* is also interesting for the reason that an analysis by Hilger of shells purporting to belong to this genus are made to be phosphatic, and practically identical in composition with those of *Lingula*. The authenticity of Hilger's material is questionable; and his analysis will not be reproduced here.

In the group of phosphatic brachiopods four analyses have been made by us. On account of the large amount of organic matter in these shells, which possibly varies with the age or maturity of the animal, we prefer to report our results, as others before us have done, in proximate rather than ultimate form.

1. *Lingula anatina*, Gmelin. Coast of Higo Province, Japan. Organic matter, rejected, 40%.

2. *Lingula anatina*, Iloilo, Philippine Islands. Organic matter, rejected, 39.5%.

3. *Discinisca lamellosa*, Broderip. Coast of Peru. Organic matter, rejected, 25%.

4. *Glottidia* (formerly *Lingula*) *pyramidata*, Stimpson. Coast of North Carolina. Organic matter about 37%. Analysis incomplete for lack of sufficient material.

Phosphatic brachiopods

	1	2	3	4
SiO_2	0.91	0.50	0.85	0.49
$(Al, Fe)_2O_3$	0.54	0.29	0.58	1.16
$MgCO_3$	2.70	0.79	6.68	1.71
$CaCO_3$	1.18	4.25	8.35	?
$CaSO_4$	2.93	4.18	8.37	?
$Ca_3P_2O_8$	91.74	89.99	75.17	74.73
	100.00	100.00	100.00	

These analyses are noteworthy, on account of the unusual proportion of calcium sulphate reported in them. *Discinisca* is especially remarkable in this respect, and also in its percentage of magnesium carbonate. Small amounts of sulphates have often been found in mollusks and corals as well as in the calcareous brachiopods, but in nothing like the proportion given here. A new analysis of *Discinisca*, made upon fresh material, is much to be desired.

In the older analyses of this group the sulphate seems to have been ignored, or at least to have escaped attention. The figures are as follows:

5. *Lingula ovalis*. Hawaiian Islands. T. S. Hunt, analyst.[5]

6, 7. *Lingula ovalis*. Locality not given. A. Hilger, analyst.[6]

8. *Lingula anatina*. S. Cloëz, analyst.[7] Recalculated to 100% after rejecting 42.6% of organic matter.

Older analyses of phosphatic brachiopods

	5	6	7	8
SiO_2	....	0.18	0.17	trace
$MgCO_3$	....	2.94	3.13	....
$CaCO_3$	11.75	10.76	10.86	12.19
$Ca_3P_2O_8$	85.79	84.94	85.24	77.17
$Mg_3P_2O_8$	....	....	....	7.03
$FePO_4$	....	0.77	0.76	3.61
$MgO(?)$	2.80	....	....	....
	100.34	99.59	100.16	100.00

In this table the relatively high figures for $CaCO_3$ are doubtless due to the neglect of the sulphate determinations. The analysis by Cloëz differs from the others principally in form, that is, in its mode of calculation. If the phosphoric oxide in it is entirely assigned to the lime, then the proportion of calcium phosphate becomes 88.6%, and well in line with the other figures. The amount of calcium carbonate would be correspondingly reduced.

Now to sum up. The brachiopods, as stated at the beginning of this paper, are to be divided into two distinct groups; the shells of one consisting mainly of calcium carbonate with little organic matter; and of

the other predominating calcium phosphate with much organic matter. The two groups, although they may be alike structurally, are physiologically quite dissimilar, the chemical reactions involved in building the shells being of two different orders. Such a distinction ought to be significant to biologists, and it is for them to determine what it means. Geologically, however, we can see that the phosphatic brachiopods have probably played some part in the formation of phosphatic sediments, a function which is shared by vertebrate animals and some crustaceans.

[1] Published by permission of the Director of the U. S. Geological Survey.
[2] Sharples, S. P., *Amer. J. Sci.*, ser. 3, 1, 168 (1871).
[3] Kunckell, F., *J. prakt. Chem.*, ser. 2, 59, 102 (1899).
[4] Schmelck, L., *Norske Nordhavs Expedition*, No. 28, p. 129 (1901).
[5] Logan, W. E. and Hunt, T. S., *Amer. J. Sci.*, ser. 2, 17, 237 (1854).
[6] Hilger, A., *J. prakt. Chem.*, 102, 418 (1867).
[7] Cloëz, S., *Jahrber. Chem.*, 1859, p. 642. From *l'Institut*, 1859, p. 240.

ON THE OCCURRENCE OF THE LINE 4686 A AND THE RELATED SERIES OF LINES IN THE SPECTRA OF THE PLANETARY NEBULAE

By W. H. Wright

LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA

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The line 4686 A and the related series of lines known as the ζ *Puppis* series, or 'sharp series' of hydrogen, were first observed in the spectra of the heavenly bodies. In 1912 Fowler succeeded in exciting them in a laboratory source.[1] More recently they have played an important rôle in certain theories of the constitution of the atom.[2]

The lines in question exist in the spectra of the planetary nebulae, and a number of facts concerning their occurrence have been brought out in the course of an investigation, now being undertaken, of these spectra. This study, while not yet complete, has led to some tentative generalizations on the behavior of certain of the nebular lines, prominent among them the one at 4686, and it may add to the significance of some of the observations of this line if a brief account is given of these. In what follows I shall attempt to state in general terms what appear to me to be the most significant facts gathered from an examination of about a dozen planetary nebulae, and shall make only occasional references to individual objects. A detailed account of all of the observations will appear on the completion of the work. The conclusions arrived at here are, of course, subject to revision in the light of additional data.

In another publication reference has been made to the fact that the nuclei of the planetary nebulae are in general Class O, or to use an older term, Wolf-Rayet stars.[3] The inquiry into the relationship between the spectra of the nebulae and their nuclei has necessitated a study of the distribution of light in the nebulae, line by line. This has been pursued by various means, only one of which need be referred to here. If the slit of the spectroscope be placed across the image of one of these usually symmetrical nebulae, those lines which are emitted throughout its full extent will be longer than those given out say only close to the center. In this way the length of a line may be taken as the measure of the extent of its occurrence in the source, just as is the case in laboratory studies of the arc, spark and other terrestial sources.

It has been found that in the majority of cases the nebulae are not homogeneous,[4] that is, lines observed in the above described manner have different lengths, and in general there is a certain order of length for the different lines. Selecting a few from the sixty or more nebular lines we may say that 4686 is always among the shortest, followed by the lines of helium, 'nebulium' and hydrogen in the order of length. An interpretation of this phenomenon on the assumption that the nebulae are in the process of condensation into stars is that the lines shrink into the nucleus in this order. We have examples of nebulae in many stages of the process. The present purpose however is not to enter into a speculative discussion of the development of stars, but to sketch the behavior of the line 4686 and the members of the related series.

The line 4686 is found in two forms: (*a*) as a narrow line in the nebulosity of some of these objects, and (*b*) as a broad band confined to the nuclei of certain others. Its occurrence in both forms in the same nebula is rare, one case only of this sort having been observed.

(*a*) *Occurring in the first form.* The line presents the appearance of a monochromatic radiation, under the strongest dispersion used, that of three dense prisms. It is generally (perhaps always) accompanied by very faint ζ *Puppis* lines (5411, 4541, 4200) of a similar character. It is to be looked for in those nebulae in which the lines 5007 and 4959 have their greatest strength relatively to the hydrogen lines. A case in point is the nebula N. G. C. 7027, the brightest known planetary. In this object the position of the line, derived from four photographs secured with a three prism spectrograph, is 4685.93, (R), a quantity in satisfactory agreement with Fowler's laboratory determination of 4685.98 (Rowland). The wave-lengths of the three related lines were measured with a dispersion of one prism. They are 5411.4, 4541.7, and 4202.2. The last value is not very trustworthy and all three are sub-

ject to revision with further observation. The agreement with the values calculated by theory: 5411.74, 4541.79, and 4200.02, is good. N. G. C. 7027 appears to be an unusually homogeneous nebula, 4686 being probably coextensive with the helium and hydrogen lines.

In addition to the ζ *Puppis* series of lines, another series lying in the ultraviolet was found by Fowler to be associated with 4686. The first member of this series, 3203, has been searched for with a quartz spectrograph attached to the Crossley reflector. It could not be photographed with a prolonged exposure, but this does not prove its nonexistence, as the reflectivity of silver is very low at 3200. It should be looked for with more suitable apparatus.

(*b*) *Occurrence as a nucleus line.* As has been remarked, the line when confined to the nucleus is broadened out into a band, which is frequently bordered on the edge of shorter wave-length by a broad dark line. The maximum of this band is commonly displaced toward the red end of the spectrum, the amount of the shift being of the order of an angstrom. The lines of the ζ *Puppis* series are present, in planetary nuclei, in some instances as bright and in others as dark bands. In this respect they parallel their behavior in Class O stars in general, as described by the observers of the Harvard College Observatory.[5] As an example we may cite the nebula B. D. $+30°3639$. The nucleus of this object is a well known Class O star, and contains numerous bright bands in addition to that at 4686. Nearly all of these are of the same width, about 10 A. A very few bands have widths of about a quarter of this amount, and among them are the members of the ζ *Puppis* series. These, with 4686, are bordered on the violet edge by broad dark lines.

In only one instance has 4686 been found to exist in both nebula and nucleus. In N. G. C. 2392 the narrow nebular line contains a knot where the continuous spectrum of the nucleus crosses it. From the apparent rarity of this condition it seems probable that the transition from one form of radiation to the other, in any progressive change which may be going on in these objects, takes place with comparative rapidity, once it has begun.

It is an unsettled question among physicists whether the lines here discussed are due to hydrogen or helium. On this phase of the matter the nebulae appear to shed no light, as they afford no indication that the radiations belong to either of these elements. Fowler however noticed certain peculiarities of their localization in vacuum tubes, and it is possible that their behavior in this respect in the planetary nebulae may lead to some understanding of the conditions obtaining in these objects.

The interesting theory of radiation proposed by Bohr, to which reference has already been made, predicts lines separated by about two angstroms from the members of the Balmer series. Their verification in the spectra of the nebulae would be a matter of great importance, but the problem presents unusual difficulties which I have not yet been able to overcome. It is possible that future efforts will meet with greater success.

An attempt has recently been made, by an excellent observer, to classify the nebulae on the basis of the intensity of 4686. The line is common to both the nebulae and the Class O stars, and in the proposed system of classification it is assumed that the brighter a line in a nebula the closer the latter approaches to the stellar type. While I believe that the line in question, with others, will eventually serve as the basis of such a classification, I am strongly of the opinion that the matter of the intensity of the line alone affords no clue to the position of the spectrum in the scale of development unless indeed it be in a sense entirely opposite to the one suggested. It is not until the line settles into the nucleus, and is practically eliminated from the nebula proper, that the Class O stage is approached. In such objects as N. G. C. 2d Index 418, N. G. C. 6826 and N. G. C. 6572, which have Class O nuclei, the line is confined to the nucleus, and is a very inconspicuous affair. In general the more prominent this line in the spectrum of a nebula the further removed is the object from the stellar stage. The nebula N. G. C. 7027 apparently has no Class O characteristics, but 4686 is among its strongest lines.

[1] *London, Mon. Not. R. Ast. Soc.*, 73, 62 (1913); E. J. Evans, *Nature, London*, 92, 5 (1913).

[2] N. Bohr, *Phil. Mag., London*, ser. 6, 26, 1 and 476 (1913); A. Fowler, *London, Phil. Trans. R. Soc.*, 214, 225 (1914).

[3] *Astrophys. J.*, December, 1914.

[4] A number of cases of non-homogeneity of nebulae have been reported by previous observers. Campbell found the hydrogen lines relatively strong in the outer parts of the *Orion* and Trifid nebulae and also of N. G. C. 2d Index 418 = S. D. M. $-12°$ 1172. See also Hartmann, *Astrophys. J.*, 21, 389 (1905). See also Burns's observations of the Ring nebula, *Lick Obs. Bul.*, 6, 92 (1910). Wolf has observed the Ring nebula in *Lyra*, by a method identical with that described in this paper, and finds 4686 to be a short line. *Sitz. Heid. Akad. Wiss.*, 27, 1 (1911).

[5] Miss A. J. Cannon, *Ann. Obs. Harvard Coll.*, 56, 66 (1912).

THE NATURE OF NERVE CONDUCTION IN CASSIOPEA

By Alfred Goldsborough Mayer

DEPARTMENT OF MARINE BIOLOGY, CARNEGIE INSTITUTION OF WASHINGTON

Presented to the Academy, March 24, 1915

The experimental side of this research was conducted at the Marine Laboratory of the Carnegie Institution at Tortugas, Florida, and the kymograph records were studied under most advantageous surroundings kindly offered in Guyot Hall, Princeton University, by Profs. Edwin G. Conklin, Ulric Dahlgren, and Louis R. Cary. Ring-shaped strips of subumbrella tissue of the scyphomedusa *Cassiopea xamachana* were cut

TABLE I

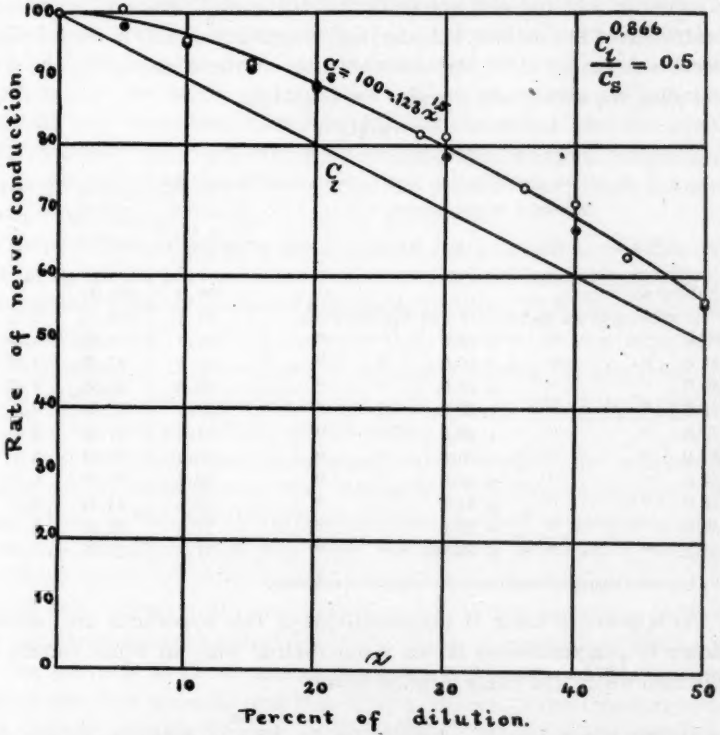
COMPOSITION OF THE SOLUTION	AVERAGE RATE OF NERVE CONDUCTION IN SEA WATER DILUTED WITH DISTILLED WATER	AVERAGE RATE OF NERVE CONDUCTION IN SEA WATER DILUTED WITH 0.415 MOLECULAR $MgCl_2$	RATE CALCULATED FROM THE FORMULA $C_x = 100 - 0.123\,x^{1.5}$ WHERE C_x IS THE RATE CORRESPONDING TO ANY PERCENT OF DILUENT, x
Natural sea water.....	100.0	100.0	100.00
95.0 volumes sea water + 5 of diluent	100.5 ± 0.67	97.9 ± 0.60	98.63
90.0 " " + 10 "	95.89 ± 0.825	95.3 ± 1.23	96.11
85.0 " " + 15 "	92.3 ± 1.21	91.6 ± 0.75	92.85
80.0 " " + 20 "	88.3 ± 1.19	88.9 ± 1.20	89.00
72.0 " " + 28 "	81.94 ± 0.48		81.78
70.0 " " + 30 "	81.4 ± 1.49	78.1 ± 0.74	79.79
64.0 " " + 36 "	73.91 ± 0.68		73.43
60.0 " " + 40 "	71.1 ± 1.29	67.2 ± 0.65	68.88
56.0 " " + 44 "	64.55 ± 1.26		64.10
50.0 " " + 50 "	56.31 ± 1.62	55.4 ± 0.76	56.50
33.3 " " + 66.7 "	29.0 ± 1		33.05

so as to remove the marginal sense organs, thus paralyzing the ring. Then a contraction wave was entrapped in the circuit, and the ring was placed in sea water diluted either with distilled water, or with 0.415 molecular magnesium chloride. The decline in rate was almost identical in similar concentrations of both these solutions although the magnesium appears to be slightly more depressant than the distilled water.

Experiments made in 1913 showed that the decline in rate of nerve conduction is the same in sea water diluted with 0.9 molecular dextrose as in sea water diluted with distilled water, and thus it is evident that down to 50% concentration the decline in rate is due solely to the change in concentration of the cations sodium, calcium and potassium, and not to the reduced osmotic pressure, or to magnesium.

Table I shows the results of the observations of 1914, the probable errors being expressed as ± following the mean. Thus 100.5 ± 0.67 means that the average rate was 100.5 with a probable error of ± 0.67.

As the table is based upon 373 observations, the probable errors are on the whole low for physiological results and are not greater than 1.62%.



If C_x be the velocity of nerve conduction corresponding to any percentage of diluent x (thus in 75 volumes of sea water mixed with 25 volumes of distilled water, $x = 25$), then

$$C_x = 100 - 0.123\ x^{1.5}$$

But a more interesting relation exists which may throw new light upon the nature of nerve conduction, for it appears that the curve representing the velocity of nerve conduction is identical in form with that for adsorption.

Past experiments show that the rate of nerve conduction in *Cassiopea* depends upon the concentration of the cations sodium, calcium, and potassium, and not upon osmotic pressure or upon magnesium. This

being so, and if nerve conduction be a chemical phenomenon, we should expect according to Wilhelmy's law that its rate would be proportional to the concentration of these three cations which take part in the reaction.

Thus if the particles of the colloidal nerve substance carry a negative charge they would attract these positive cations to their surfaces, in accordance with the well known formula $C_s = \beta C_l^{1/p}$ where C_s is the concentration of the sodium, calcium, and potassium cations in the colloidal nerve substance; C_l is the concentration of these cations in the surrounding sea water; and β and p are constants.

TABLE II

COMPOSITION OF THE SOLUTION	C_l RELATIVE CONCENTRATION OF THE CATIONS Na, Ca, AND K IN THE DILUTED SEA WATER	C_s OBSERVED RATE OF NERVE CONDUCTION	$\frac{C_l^{0.866}}{C_s}$
Natural sea water	100.0	100.00	
95.0 volumes of sea water + 5.0 of distilled water	95.2	100.50	0.51
90.0 " " + 10.0 " "	90.5	95.89	0.51
85.0 " " + 15.0 " "	85.5	92.30	0.51
80.0 " " + 20.0 " "	80.8	88.30	0.50
72.0 " " + 28.0 " "	73.3	81.94	0.50
70.0 " " + 30.0 " "	71.4	81.40	0.49
64.0 " " + 36.0 " "	66.0	73.91	0.52
60.0 " " + 40.0 " "	62.2	71.10	0.50
56.0 " " + 44.0 " "	58.4	64.55	0.52
50.0 " " + 50.0 " "	52.8	56.31	0.55
33.3 " " + 66.7 " "	37.5	29.00	0.79*

*Injurious osmotic effects are produced by this extreme dilution.

As appears in table II the conditions of this hypothesis are fulfilled down to concentrations of sea water diluted with an equal volume of distilled water, the exact formula being

$$C_s = 2.0\, C_l^{\frac{1}{1.154}}. \quad \text{Hence } \frac{C_l^{0.866}}{C_s} = 0.5.$$

As the rate of nerve conduction must according to Wilhelmy's law be proportional to C_s, we may substitute it for C_s.

Thus apparently the velocity of nerve conduction is proportional to the degree of concentration of the cations sodium, calcium and potassium which are drawn from the surrounding sea water and concentrated by adsorption upon the surface of some undetermined negatively charged colloidal particles of the nerve. In fact the nerve stimulus which produces pulsation appears to be conducted by these cations themselves, taking part in some reversible chemical reaction accelerated by an enzyme.

The presence of these positively charged cations must tend to reduce the surface tension of the colloidal particles, and with it the negative potential. In fact the sudden augmentation of the negative charge upon any one of the colloidal particles would attract other positive cations from the surfaces of neighboring particles and initiate a local negative potential which would travel through the nerve.

It is more probable however that, as the velocity of nerve conduction is proportional to the degree of concentration of the adsorbed sodium, calcium, and potassium cations, these cations themselves initiate the reaction and form some reversible chemical compound with some proteid substance, thus temporarily neutralizing their positive charges and unmasking the negative charges upon the colloidal particles to the surfaces of which they were attracted by adsorption.

These various hypotheses are suggested not so much as possible explanations of the phenomenon of nerve conduction, but more to stimulate interest in the problem and to suggest directions for further research. It is perhaps a step in advance to know that, whatever its precise nature, nerve conduction is some chemical reaction involving the adsorbed sodium, calcium, and potassium cations, and thus its rate is proportional to the concentration of these adsorbed ions.

The almost instantaneous recovery observed when the medusa is taken out of dilute sea water or magnesium solutions and replaced in natural sea water, and the very short time required to assume a constant rate of nerve conduction when the medusa is placed in concentrated or diluted sea water is readily explained by the theory that nerve conduction is dependent upon the adsorption of the conducting cations by negatively charged colloidal particles and is thus a surface effect.

The previous work of Meltzer and Auer, Mines, and Mayer has shown that it is probable that the calcium enters into combination with the sodium, possibly forming an ion-proteid. It now seems probable that this intimate association between calcium and sodium takes place upon the surfaces of the particles of the colloidal nerve fluid or some other colloidal elements of the nerve.

In this brief summary it may be inexpedient to review the literature of the subject, but the bearing of this research upon the observations of Macallum, 1913, upon changes in surface tension in active cell membranes, and of Tashiro, 1914, upon the production of carbon dioxide by active nerves (see these *Proceedings*, **1**, 110), is apparent, and the contention of R. S. Lillie that cell surfaces play the important rôle in stimulation is strongly supported.

It is a great pleasure to express my sense of indebtedness to Dr. E. Newton Harvey, Prof. George Augustus Hulett, and Dr. Stewart Paton of Princeton University for timely advice and aid.

A NEW CANONICAL FORM OF THE ELLIPTIC INTEGRAL

By Bessie I. Miller

DEPARTMENT OF MATHEMATICS, JOHNS HOPKINS UNIVERSITY

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The elliptic norm curve E_n in space S_{n-1} admits a group G_{2n}^2 of collineations, and in fact there is a single infinity of such curves which admit the same group. A particular E_n of the family is distinguished by a value of the parameter τ, itself an elliptic modular function defined by the modular group congruent to identity (mod n).

In the group G_{2n}^2 there are certain involutory collineations with two fixed spaces. If E_n is projected from one fixed space upon the other, a family of rational curves R_m mapping the family of E_n's, is obtained. The quadratic irrationality separating involutory points on E_n involves the modulus τ and the parameter t of the R_m. When the genus of the modular group is zero and $n = 3, 4, 5$, the irrationality can be used to define the elliptic parameter

$$u_1 = \int \frac{(t\,dt)}{(t\,\tau)\ \alpha_\tau^{r-3}\,\alpha_t^3},$$

where α_t^r is the tetrahedral, octahedral, or icosahedral form. This is in contrast to Klein's form[1] as developed by Bianchi,[2] for there the normal elliptic integral is a rational curvilinear integral along an elliptic curve.

A comparison of the two integrals is more illuminating if it is carried out for a special case. Let E_n be E_5 in S_4. In Bianchi's notation the five quadrics having E_5 as their common intersection are

$$\varphi_i : a\,x_i^2 + a^2\,x_{i+2}\,x_{i+3} - x_{i+1}\,x_{i+4} = 0,\ (x_{i+5} \equiv x_i),\ (i = 0, \cdots 4),$$

where a is the modulus. If a transformation of coordinates is made in order to bring into evidence the fixed spaces of the involutory collineation used in the projection, then the icosahedral form which appears in the irrationality is

$$\alpha_t^{12} = t_1\,t_2\,(t_1^{10} + 11\,t_1^5\,t_2^5 - t_2^{10}).$$

The integral u_1 involving $\tau = a$ explicitly in a rather simple form is uniquely defined. Moreover it is invariant under all cogredient trans-

formations of t and τ, which leave the form α_x^{15} unaltered, i.e., the sixty transformations of the icosahedral group applied simultaneously to t and τ, the parameter of the doubly-covered conic R_2 and the modulus of the elliptic quintic curve E_5, leave u_1 unaltered.

Consider now Bianchi's integral. It is defined as

$$U = C \int \frac{(u\,dv - v\,du)}{(\varphi_0\,\varphi_1\,\varphi_2\,u\,v)},$$

where C is a constant, u and v any two expressions linear in x, and the denominator is the functional determinant of φ_0, φ_1, φ_2, u and v. For a particular choice of u and v the integral assumes the simple form

$$U = C \int \frac{(x_0\,dx_1 - x_1\,dx_0)}{5\,a^3\,x_2\,x_4 - (2\,a^5 + 1)\,x_0\,x_1},$$

where the x's are subject to the relations φ_i. Different expressions for U can be obtained by making different choices for u and v. Hence there is no unique form for U as there is for u_1. The integral U assumes various conjugate forms under the Group G_{60} of collineations on the x's, and also under the transformations of a.

So the integral u_1 seems to have an advantage over U in its simplicity of form, its uniqueness, and its invariancy under transformations.

By a study of the integral u_1 itself some interesting results are derived. The modular equation connecting τ and J, the absolute invariant of u_1, can be deduced as the result of the binary syzygy of lowest weight connecting the concomitants of α_x^r. The requirement that the Riemann surface attached to the modular equation be regular leads to the modular equations associated with the regular bodies. It is then possible to eliminate the more tedious individual proofs used by Bianchi in the discussion of the moduli of E_3 and E_5 to show that these moduli are the tetrahedral and icosahedral irrationalities respectively. In fact the algebraic discussion carried out once for α_x^r is complete for factor groups of genus zero, which have been discussed by Klein,[3] i.e., those isomorphic with the groups associated with the regular bodies, namely, the one dihedral group G_6 and the tetrahedral, octahedral, and icosahedral groups.

[1] Klein-Fricke, *Vorlesungen über die Theorie der Elliptischen Modulfunctionen*, Bd. 2, Abschnitt 5.

[2] Bianchi, Über die Normalformen dritter und fünfter Stufe des elliptischen Integrals erster Gattung, *Math. Ann., Leipzig*, 17, 234–262, (1880).

[3] Klein-Fricke, loc. cit., vol. 1, pp. 339 ff.

THE STRUCTURE OF COMPLEX ATOMS AND THE CHANGES OF MASS AND WEIGHT INVOLVED IN THEIR FORMATION

By William D. Harkins and Ernest D. Wilson

KENT CHEMICAL LABORATORY, UNIVERSITY OF CHICAGO

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A study of the atomic weights referred to hydrogen as unity shows that for the series of elements from helium to fluorine the average deviation from a whole number is 0.09 units, which is smaller than would be expected if the atomic weights were wholly the result of accident. However, the average deviation for the first 27 elements (0.21) is almost as great as would be expected as the result of chance (0.25 units). This, on first sight, does not seem to accord well with the numerical form of Prout's hypothesis, that these atomic weights should be whole numbers. If now the atomic weights referred to oxygen are considered, the remarkable relation is found that the numbers are exceedingly close to whole numbers as a rule. In order to save space these relations may be considered in the form of the results of calculations of probability. The chance that the sum of the deviations from whole numbers for the 27 lighter elements should be as small as it is when hydrogen is taken as 1 is found to be one chance in ten, when the method used for the calculation is of the form known as De Moivre's problem, and when the probable errors in the atomic weights are taken into account. In contrast with this it is found that there is only about one chance in fifteen million that the sum of the deviations from whole numbers of the atomic weights on the oxygen basis should be as small as it is.

This might seem to indicate that the atoms other than hydrogen are built up from units different from hydrogen and of a weight 1.000, while hydrogen has a weight 1.0078 (on the oxygen basis); but this would involve the existence of two kinds of particles with masses very nearly the same, and gives the additional difficulty that the atomic weights are not exact multiples of 1, which indicates that if the particle from which the atoms are built has a weight of nearly 1, this weight must vary somewhat from atom to atom. Attempts have been made to explain the discrepancy as the result of a variation in the number of negative electrons, but this method is neither in accord with recent theories of atomic structure, nor does it seem to agree with the fact that the atoms are neutral electrically.

If the assumption is made that the other atoms are hydrogen complexes, then it is found that in the formation of the complex there must result a change of weight which is in general negative in sign. The percentage decrease in weight may be called the packing effect, and the average value of this effect for the 27 lighter elements in 0.77%. The magnitude of this effect is nearly constant, as is shown by the value 0.77 for helium, while for the six elements from boron to sodium the packing effects are 0.77, 0.77, 0.70, 0.77, 0.77, and 0.77%. Since the value of the packing effect is −0.77% for oxygen, and this is the average packing effect of the 27 elements as well as the value of the effect for a considerable number of the different atoms, it is seen that the use of a whole number as the atomic weight of oxygen makes allowance for this effect and so gives to the other elements atomic weights which are whole numbers or very nearly whole numbers.

In order to determine a cause for this decrease in weight which must result if the other atoms are built up from the nuclei of hydrogen atoms as units, it will be well to consider if this effect may not be due to the overlapping of the fields of the charged particles which unite to form the *nucleus* of the complex atom. Recent work shows that this nucleus is extremely small. Rutherford, from data on the scattering of alpha particles in passing through thin gold leaf, has calculated the *upper* limit of the nucleus of the gold atom as 3.4×10^{-12} cm., and Darwin found the similar value for hydrogen to be about 0.8×10^{-13} cm., which is of the order of size of the negative electron as usually considered. If the gold nucleus is built up of hydrogen nuclei this would mean that it would contain about 197 hydrogen nuclei and 118 negative electrons in its extremely minute volume, if the idea of van den Broek and Moseley[1] that the positive charge on the nucleus is equal to the atomic number is used for the calculation. Thus over 300 particles would be contained in a volume which according to Rutherford's calculation has a radius of only 3.4×10^{-12} cm. as its upper limit of value. It must be emphasized that in this paper only the electrons contained in the nucleus of the atom are the ones which are considered, and that the distance of the external electrons, sometimes considered as of the order of the assumed radius of the atom as about 10^{-8} cm., has absolutely nothing to do with the packing effect.

The simplest case for an actual nucleus which could be calculated, is that of helium, which may be assumed to contain four positive particles and two negative electrons. However, the arrangement of these particles is not known, so the solution will be given for the case of a single positive and a single negative electron. That a change in mass

will result if these two particles are brought very close together, is suggested by Lorentz,[2] but he calculates neither the sign nor the magnitude of the effect, nor does he indicate how the calculation may be made. The symbols used are $\mathbf{G}$ = electromagnetic momentum per unit volume, $\mathbf{H}$ = magnetic intensity vector, $\mathbf{E}$ = electric intensity vector, $\mathbf{S}$ = Poynting's vector for magnetic flux, c is the velocity of light, and $[\mathbf{AB}]$ represents the vector product.

Now $\mathbf{G} = [\mathbf{EH}]/c = \mathbf{S}/c^2$, and for the field due to a system of charges

$$\frac{[\mathbf{EH}]}{c} = \frac{\left[\left(\sum_i \mathbf{E}_i\right)\left(\sum_j \mathbf{H}_j\right)\right]}{c} = \frac{\sum_i [\mathbf{E}_i\mathbf{H}_i]}{c} + \frac{\sum_{(ij)} [\mathbf{E}_i\mathbf{H}_j]}{c}$$

where the summation $\Sigma_{(ij)}$ is the vector product of each i with each j. The first summation gives the electromagnetic momentum which would be due to the particles if their fields did not overlap, and the second term gives the effect of the overlapping of the fields. This may be called the "Mutual electromagnetic momentum," and is designated by $\overline{\mathbf{G}}$.

For point charges $E_1 = \dfrac{(1-u^2)e_1}{4\pi r^2(1-u^2\sin^2\theta_1)^{3/2}}$. Let $(1-u^2) = K^2$ and $(1-u^2\sin^2\theta_1) = \beta_1^2$. The transverse component of E due to the two particles 1 and 2 is

$$E_t = \frac{K^2 e}{4\pi}\left\{\frac{\sin\theta_1}{r_1^2\beta_1^3} \mp \frac{\sin\theta_2}{r_2^2\beta_2^3}\right\}$$

where the sign is positive if the charges have the same sign, and *negative if they are of opposite sign*. As only the longitudinal component of the vector $\mathbf{G}$ is desired, only the transverse component of $\mathbf{E}$ is needed. Then $H = uE\sin\phi/c$, where ϕ = the angle between E and the direction of u.

If E_t is used, $\phi = 90°$, and $H = u\,(E_1\sin\theta_1 \mp E_2\sin\theta_2)/c$. Hence

$$\mathbf{G} = \frac{[\mathbf{E}_t\mathbf{H}]}{c} = \frac{u}{c^2}(E_1\sin\theta_1 \mp E_2\sin\theta_2)(E_1\sin\theta_1 \mp E_2\sin\theta_2),$$

$$\text{and } \overline{\mathbf{G}} = \mp\frac{2u}{c^2}\int E_1E_2\sin\theta_1\sin\theta_2 d\tau = \frac{2uK^4e^2}{c^2(4\pi)^2}\int\frac{\sin\theta_1\sin\theta_2}{r_1^2r_2^2\beta_1^3\beta_2^3}d\tau.$$

Now $r^2\beta^2 = r^2 - u^2(r^2\sin^2\theta)$ and $r^2\sin^2\theta = y^2$. Let $a = \frac{1}{2}$ distance between e_1 and e_2. Neglecting all terms in u^2, and placing $d\tau = 2\pi y dy dx$, we have

$$\overline{\mathbf{G}} = \mp\frac{uK^4e^2}{8c^2\pi^2}4\pi\int_0^\infty\int_0^\infty \frac{y^3dydx}{\sqrt{\{[(x-a)^2+y^2][(x+a)^2+y^2]\}^3}}$$

which is obtained by making use of the symmetry of the equation. The evaluation of this integral gives the value $1/2a$ so $\bar{G} = \pm uK^4e^2/(4\pi ac^2)$. The mass represented by this value of $\bar{G}$ is $\Delta m = \pm e^2/(4\pi ac^2)$ where Δm is the change of mass due to the overlapping of the fields of the electrons. Now the longitudinal mass is $m_1 = e^2/(6\pi c^2 R)$ where R = radius of the electron. By division $\Delta m/m_1 = 3R/2a$, where a equals one-half the distance apart of the electrons.

Taking R as the radius of the positive electron, and -0.77% as the packing effect, it is seen that in this simple case the distance apart of the positive and the negative electrons would be 400 times the radius of the positive electron. However, the system used for the calculation does not correspond to any actual atom, but if it is considered that the gold nucleus is *smaller* than corresponds to a radius of 3.4×10^{-12} cm., as Rutherford calculates, then when it is considered that the large number of positive and negative electrons contained in this space must make up a very complex system, undoubtedly with a special structure, it is evident that the distances of the electrons as calculated to give the observed packing effect, is of the right order of magnitude to give a gold nucleus of the kind supposed by Rutherford's theory.

The Hydrogen-Helium System. Fajans,[3] Soddy,[4] Russell,[5] von Hevesy,[6] and Fleck,[7] have proved that when a radioactive element ejects an alpha particle, found by Rutherford to have a mass of 4 units, and to give ordinary helium gas, the new substance produced has different properties and a different valence from the parent material. The change is such that the new element lies two groups to the left in the periodic table and therefore has an atomic number and a valence with values two less than before. Now that this relation has been found to apply to elements of high atomic weights, the question arises as to whether the same relations hold for the lighter atoms which have not been found to give an appreciable alpha disintegration. If they do, then the atomic weights of the elements of even atomic number could best be found by beginning with helium, and adding a weight of 4 for each step of two atomic numbers, and by proceeding in the same way beginning with lithium for the odd numbered elements. This gives:

Atomic number even = 4 8 12 16 20 24 28 32
Atomic number odd = 7 11 15 19 23 27 31 35

which are on the whole the correct atomic weights. The system obtained in this way may be best represented in the form of a periodic table as in the table.

When given in this way it is seen that the atomic weights not only follow the helium system derived from the behavior of the radioactive

elements, but in addition, after this has been applied it is seen that there is a great regularity in the number of hydrogen atoms, H_3, which must be included to give the atomic weights of the elements of odd atomic number.

The table gives an explanation of the fact that the atomic weight of argon is higher than that of potassium while its atomic number is lower. This is seen to be due to the general tendency for the increment between the third and fourth series to take the value 5He, and in this sense it is the potassium and calcium which are irregular in behavior, and not the argon. In this part of the table there is seen to be a tendency to add 2He instead of 1He for one step between elements of even atomic number.

SYMBOLIC REPRESENTATION OF THE ATOMIC WEIGHTS ACCORDING TO THE HELIUM SYSTEM DERIVED FROM THE BEHAVIOR OF THE RADIOACTIVE ELEMENTS IN THEIR ALPHA DISINTEGRATIONS

H DETD. = 1.0078

GROUP	0	1	2	3	4	5	6	7	8	
Series 2	He	Li	Be	B	C	N	O	F		
	He	$He+H_3$	2 He+H	$2 He+H_3$	3 He	$3 He+2 H$	4 He	$4 He+H_3$		
Calc.		7.	9.	11.	12.	14.	16.	19.		
Detd.	4.	6.94	9.1	11.	12.	14.01	16.	19.		
Series 3	Ne	Na	Mg	Al	Si	P	S	Cl		
	5 He	$5 He+H_3$	6 He	$6 He+H_3$	7 He	$7 He+H_3$	8 He	$8 He+H_3$		
Calc.	20.	23.	24.	27.	28.	31.	32.	35.		
Detd.	20.	23.	24.3	27.1	28.3	31.02	32.07	35.46		
Series 4	A	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co
	10 He	$9 He+H_3$	10 He	11 He	12 He	$12 He+H_3$	13 He	$13 He+H_3$	14 He	$14 He+H_3$
Calc.	40.	39.	40.	44.	48.	51.	52.	55.	56.	59.
Detd.	39.88	39.1	40.07	44.1	48.1	51.	52.	54.93	55.84	58.97

Increment from series 2 to series 3 = 4 He.
Increment from series 3 to series 4 = 5 He. (For K and Ca = 4 He.)
Increment from series 4 to series 5 = 6 He.

If a weight of 4 is added for each increase of 2 in the atomic number, then the average increase of the atomic weight per atomic number should be 2, and that this is in accord with the facts is shown by the atomic weights of neon and calcium. These elements have the atomic numbers 10 and 20, and the atomic weights, $10 \times 2 = 20$, and $20 \times 2 = 40$. The equation[8] which gives the atomic weights of the lighter elements is $W = 2n + \frac{1}{2} + \frac{1}{2}(-1)^{n-1}$, where n is the atomic number. In order to include the heavier elements it is necessary to insert another term, the meaning of which will be considered in a later paper, to account for the tendency of the increment of weight to become greater as the atomic weight increases, as follows: $W = 2(n + n') + \frac{1}{2} + \frac{1}{2}(-1)^{n-1}$.

That no system can explain the atomic weights of the heavier elements, unless account is taken of the fact that different series of ele-

ments exist, is evident when it is considered that the isotopes of lead, radium B, and lead from radium, differ in atomic weight by eight, or by 4%, and even in the case of some of the lighter elements that a part of the irregularity may be due to the existence of isotopic forms is indicated by the discovery by Thomson and Aston that neon, formerly supposed to have an atomic weight of 20.2, consists of two isotopes of atomic weights 20 and 22. It has been proved by Fajans and others, as has been mentioned, that the helium system holds for the heavy radioactive elements; in this paper it is shown that it also holds for the 27 lighter elements, which would seem to make it almost certain that it holds for the other elements when the proper allowances are made for variations in packing effect, and differences of series.

For the elements from helium to iron the average value of the packing effect is 0.78 units, which is, so far as the accuracy of the atomic weights allows us to determine, the same as the decrease in weight which would occur if four hydrogen atoms were to be transformed into one of helium. This means that if any element of higher atomic weight is built up entirely of helium atoms, then, on the average, the decrease in mass is practically entirely due to the primary formation of the helium atoms, and not at all to the aggregation of these into the heavier atoms. From this point of view an atom composed entirely of helium units would have extreme instability in relation to its disintegration into helium units, in comparison with its instability with reference to a hydrogen decomposition. Such an atom in a radioactive transformation should lose alpha particles very much more readily than hydrogen nuclei, in fact, if it is remembered that even the alpha decomposition does not occur appreciably for many of the known elements, it will be seen that it is doubtful if such an atom would ever give a detectable hydrogen disintegration.

If the elements of higher atomic weight are built up exactly according to the special system presented in the table, according to which the members of the even numbered groups are in general aggregates of helium alone, then since all of the radioactive elements which are *now known* to give a simple alpha disintegration, belong to even numbered groups, they could not be expected to give hydrogen upon disintegration. Thus one of the chief objections to the theory that the atoms are hydrogen complexes, which is based on the fact that up to the present time no hydrogen has been detected as the product of any radioactive change, is seen to be not contrary to, but rather in accord with the theory as here presented. However, the value of this idea is lessened by the fact that there is no evidence that the exact relations between

the composition of the odd and even groups as found for the elements of smaller atomic weight hold so far into the system as the radioactive elements. The general form of the system indicates at least that the heavy atoms contain more helium than independent hydrogen units, and this seems in accord with the fact that uranium loses alpha particles in eight steps without any apparent loss of a hydrogen nucleus.

The stability with which the hydrogen nuclei which are not contained in helium groups, but which generally occur in threes (H_3 in the table), are built into the complex atom is not in general indicated with any degree of accuracy, but in the case of lithium it seems to be great, for lithium shows the extremely large packing effect equal to 1.57%, which might seem doubtful if it were not for the extreme care taken by Richards and Willard[9] in the determination of the atomic weight of lithium. The atomic weight of hydrogen used in these papers (1.0078) is probably not in error[10] by so much as one part in 5000.

The hydrogen-helium system here presented is entirely in accord with, but independent of, the astronomical theory that the order in which the elements appear in the stars is first nebulium, hydrogen and helium, then such of the lighter elements as calcium, magnesium, oxygen, and nitrogen, and finally iron, and the other heavy metals, although in the present system it has not been found necessary to include nebulium. Some of the nebulae give bright line spectra of nebulium, hydrogen and helium; such Orion stars as those of the Trapezium give lines for hydrogen and helium; while those that are more developed show magnesium, silicon, oxygen and nitrogen, and some of the other low atomic weight elements in addition. Bluish white stars such as Sirius give narrow and faint lines for iron, sodium, and magnesium, and the solar stars give a much weaker hydrogen spectrum, and many more and stronger lines for iron and the heavy metals.[11] The astronomical theory that the heavier elements are thus formed from those of smaller atomic weight is of extreme interest, but the evidence for it is somewhat uncertain, since it is possible that it is the difference in the density of the different elements which is the effective factor in causing the spectra to appear in the order in which they are found to occur. The relative brightness of the different lines varies greatly, such lines as the calcium H and K lines being extremely strong, and this also interferes with the determination of the order of the appearance of the elements in the stars. On the other hand the evidence presented in these papers seem to give some support to the theory of the evolution of the heavier atoms from those which are lighter, but the hydrogen-helium

system here presented has the support of much better evidence than that for atomic evolution from the standpoint of astronomy alone.

We wish to thank Professor A. C. Lunn of the Department of Mathematics, for outlining for us the method for determining the distances between the positive and negative electrons.

[1] Moseley, *Phil Mag., London*, **26**, 1024; **27**, 703.
[2] Lorentz, *The Theory of Electrons*, p. 47.
[3] K. Fajans, *Physik. Zs., Leipzig*, **14**, 131 and 136.
[4] F. Soddy, *Chem. News, London*, **107**, 97; *Jahrb. Radioakt.*, **10**, 188.
[5] Russell, *Chem. News, London*, **107**, 49.
[6] Von Hevesy, *Physik. Zs., Leipzig*, **14**, 49.
[7] Fleck, *Trans. Chem. Soc.*, **103**, 381 and 1052.
[8] Rydberg, *Zs. anorg. Chem., Hamburg*, **14**, 86–7.
[9] Richards and Willard, *J. Amer. Chem. Soc.*, **32**, 4 (1910).
[10] W. A. Noyes, *Textbook of Chemistry*, p. 72.
[11] Hale, *The Study of Stellar Evolution.*

HUNTINGTON'S CHOREA IN RELATION TO HEREDITY AND EUGENICS

By C. B. Davenport

STATION FOR EXPERIMENTAL EVOLUTION, CARNEGIE INSTITUTION OF WASHINGTON

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It is now generally conceded that predisposition plays an important rôle in mental disorder but the views as to the nature of its part are very diverse and hazy. Some investigators conclude that there is an inheritance of a particular type of mental trouble, while others conceive that only a general psychopathic constitution is inherited. Again a difference of view maintains as to the nature of the recognized mental 'diseases'—by some these are regarded as distinct 'entities,' manifestations of a single, indivisible, disturbing factor. Others conceive of them as syndromes or chance associations of symptoms. Even those who hold the latter view would perhaps except as the one clear case of a neuropathic entity the condition known as 'Huntington's Chorea.' This chorea is defined by the following traits: (1) persistent tremors of the head, appendages and trunk; (2) the onset of such tremors in middle or late life; (3) the progressive nature of the tremors; and (4) progressive mental deterioration. These characters are frequently found together; is their association a necessary one?

A study of four family complexes in eastern Long Island, south-western Connecticut, south-central Connecticut and eastern Massachusetts which show nearly a thousand cases of Huntington's chorea yields the

remarkable result that practically all can be traced back to some half-dozen individuals, including three (probable) brothers who migrated to America during the 17th century. But, already, numerous 'biotypes' having specific and differential hereditary behavior have appeared. Thus there is a biotype in which the tremors are absent but mental deterioration present; a biotype in which the tremors are not accompanied by mental deterioration; a biotype in which the chorea does not progress; and a biotype in which the onset of the choreic movements is in early life. In general, the symptomatology of chronic chorea is dissimilar in different strains of families. The age of onset, the degree of muscular involvement, the extent of mental deterioration all show family differences and enable us to recognize various species, or biotypes, of the disease. These biotypes are less striking than they would be were it not for the extensive hybridization that is taking place between biotypes in random human matings.

The method of inheritance of some of the elements of Huntington's chorea has been worked out. In general, the choreic movements never skip a generation and in other respects show themselves clearly to be a dominant trait. The mental disorder is usually of the hyperkinetic or manic type and this also shows itself as a dominant. The age of onset *apparently* tends to diminish in successive generations—'law of anticipation'—but this is partly, if not wholly, illusory and is due to the fact that in comparing the age of onset in grandfathers with that in grandchildren we are not comparing on the same basis, for the grandparents are a selected lot (selected on the basis of late onset—at least late enough for them to become parents), while grandchildren include those in whom the onset is so early in life that they will never marry. If instead of comparing the average age of onset in successive generations, one compares the age of onset in a number of choreic parents, *their* parents and their grandparents, then the evidence for anticipation vanishes. Eight such series give for average age of onset of the propositus 35.5 years, parent 38.8, grandparents 36.9. In this series we can see no evidence of anticipation.

Among the 3000 odd relatives of the 962 choreics studied many nervous traits are recorded. Thus epilepsy is recorded 39 times, infantile convulsions 19 times, meningial inflammations and brain fever 51 times, hydrocephaly 41 times, feeblemindedness 73 times, Sydenham's chorea 11 times, and tics 9 times, mostly in one small family. This incidence, which would seem high for an unselected population, suggests that chorea occurs in families characterized by a general liability to nervous and mental troubles.

Though it can be shown that the 962 cases of chorea originated from 6 or 7 ancestors and that the tendency has been handed down almost without a break through the generations and that for generations there have been individuals who recognized the hereditary nature of the disease and were influenced in marriage accordingly; nevertheless, there is no clear evidence that persons belonging to the choreic lines voluntarily abstain to any marked degree from, or are selected against, in marriage.

THE ALCYONARIA AS A FACTOR IN REEF LIMESTONE FORMATION

By L. R. Cary

DEPARTMENT OF BIOLOGY, PRINCETON UNIVERSITY

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The early students of coral reef formation based their conclusions concerning the depth at which reef formation could take place and the rate at which material was added to such reefs upon the known bathymetrical distribution and growth rate of stony corals (Madreporaria). The results obtained from the examination of the cores from borings made at the Island of Funafuti in the South Pacific showed that, in this particular region at least, calcareous algae of the genus *Halimeda* were a very important factor in reef limestone formation. Among the other group of lime secreting animals, those species of Alcyonaria, which form a massive skeleton have received proper recognition as contributing to reef formation. The remaining representatives of this group have been neglected as reef formers because their limy secretion is laid down in the form of minute spicules which are set free at the time of the disintegration of the living tissues of the colony leaving no recognizable skeleton.

On most coral reefs in all parts of the world the Alcyonaria with free spicules are much more abundant than those forming a massive skeleton while in many regions they constitute by far the greatest part of all lime secreting organisms living permanently attached to the bottom. On many reef areas in the Florida-Antillean region the areas occupied by stony corals and calcareous algae are relatively small while flexible alcyonaria or the family Gorgonaceae make up the most characteristic feature of the fauna. The spicules of these organisms are found in practically all bottom samples both from the crests of the reefs and in the soft mud from the channels between the reefs so it is evident that they may be incorporated into the reef limestones before they have undergone marked erosion.

In order to determine the amount of material contributed to reef formation, during any given time, by the gorgonians, three factors must be taken into consideration: first, the amount of lime held as spicules in the tissues of these colonies; second, the bulk of the gorgonians present on any reef area; and third, the number of colonies which will set free their spicules through the death and subsequent disintegration of their coenenchyma.

1. *Spicule content.* In making the determination of the amount of spicules for any species the colony was removed from the reef without injury to any portion except the expanded base, which was always discarded as it was difficult to separate from it fragments of limestone from other sources. The colony was then weighed while still wet, cut into small pieces and the living tissue destroyed by treatment with a cold 25% solution of caustic soda. When the organic material had been dissolved the spicules were washed in rain water until no trace of organic matter remained, collected on a weighed filter, dried in a water bath kept at 100°C. and after cooling in a dessicator to room temperature, carefully weighed. By this procedure the proportion of spicules to the fresh weight of the colony could be estimated for any collection of gorgonians by simply separating the several species and determining the weight of each one.

As previous studies upon the growth rate and ecology of the gorgonians of this region had shown that at least nine-tenths of the bulk of these organisms on any reef is made up of not more than twelve species, the spicule determinations were consequently restricted to these forms. The results of analyses of the twelve most common species is shown in the table in which the figures given represent the average of five determinations for each species.

AVERAGE WEIGHT IN POUNDS AND PERCENTAGE OF SPICULES IN GORGONIAN COLONIES

Species of gorgonian	*Average weight of colonies*	*Percent spicules*	*Species of gorgonian*	*Average weight of colonies*	*Percent spicules*
Briareum sp.	2.00	26.66	Plexaurella dichotoma	0.75	35.86
Eunecia rousseaui	1.00	35.60	Plexaurella sp.	0.75	24.92
Eunecia crassa	0.30	22.66	Gorgonia flabellum	1.00	22.33
Plexaura flexuosa	1.00	30.66	Gorgonia acerosa	3.00	19.75
Plexaura homomalla	1.50	27.41	Gorgonia citrina	0.25	35.05
Pseudoplexaura crassa	2.50	21.48	Xiphigorgia anceps	0.25	25.83

Average proportion of spicules for all species 27.40%

The determinations given above were made primarily to afford a basis from which the spicule content of large masses of gorgonians could be calculated and in order to have a check for these computations a series

of twenty analyses were made of the gorgonians growing upon a square yard of the surface of widely separated reefs. The bulk of the gorgonians varied from 1.5 pounds to 25.0 pounds, the spicule content from 0.45 pounds to 6.94 pounds, for the different squares. The average for all determinations was 7.746 pounds of gorgonian colonies containing 2.1225 pounds of spicules.

2. *Distribution of gorgonians on the reefs about Tortugas.* To determine the distribution of the species of gorgonians included in the foregoing analyses on the reefs about Tortugas a series of lines were laid out extending over a number of the most important reefs and along these lines counts of the number of gorgonians occurring on a square yard were made at regular intervals, with the following results:

	Squares	*Average number of colonies*	*Number barren squares*
Line No. 1	45	5.72	8
Line No. 2	150	8.97	14
Line No. 3	30	10.86	3
Line No. 4	25	7.62	1
Line No. 5	40	13.27	7
Line No. 6	36	5.86	5

In these counts the number of colonies was alone recorded for each square yard. The weight of the mass of gorgonians on any square was estimated upon the basis of the determinations shown in the second column of the first table in which the figures represent the average weight for twenty medium sized colonies of each species.

Computed upon this basis the average weight of the gorgonians from each square along line No. 1, as given above, is 7.32 pounds. Estimating the spicule contents on the basis of the figures obtained from the analyses recorded in the table it is shown that there would be two pounds of spicules in the gorgonians from any square yard of reef area along this line. This result approaches very closely the amount found by actual analyses of the colonies from twenty representative squares. The number of colonies to the square along this line was the smallest found in the counts on any of the reefs so that when estimated upon the same basis the spicule content of the gorgonians on the squares along the lines on any of the other reefs would be greater than that found by actual analyses for the twenty squares previously mentioned. Using the smaller figure, which is well below that obtained by careful observation, the amount of lime held as spicules in the tissues of living gorgonians on a representative acre of reef area is 5.28 tons.

3. *Disintegration of the gorgonian colonies and the addition of their spicules to the reef building materials.* The spicules held in the tissues

of Gorgonian colonies represent only a potential contribution to reef formation. The actual number of gorgonians destroyed on any reef area in a given year can not be determined save by actual observation extending over the entire period, a method that had been impossible to carry out. A considerable number of observations bearing directly upon this phase of the subject has, however, been accumulated in the course of ecological studies on the gorgonians of the Tortugas regions, extending over a period of five years.

These observations have shown that when a gorgonian colony is removed from its place of attachment on the reef and allowed to lie on the bottom where it will be moved by the action of tidal currents death follows within a short time. The amount of time necessary for the complete disintegration of the coenenchyma of a colony of each of the several species which make up the most important elements in the gorgonian fauna about Tortugas was determined. This series of observations showed that when torn from the bottom, the most resistant form—Gorgonia flabellum—would be disintegrated within 120 hours, while a colony of Pseudoplexaura crassa would be broken down in 18 hours. Under normal conditions of the reefs the greatest number of the axial skeletons of dead colonies are found in positions which indicate that the tearing of the colony from its normal attachment by wave action is the cause of the greatest mortality among these animals. When destroyed in this manner the spicules of any gorgonians would be added to the limestone forming materials on the reef within a few days, at most, from the time when the colony was torn from its place of attachment and consequently before the spicules had undergone any noticeable erosion.

Next to the destruction by wave action (storms) the greatest mortality of the gorgonians is brought about by the overgrowth of their tissues by other organisms. The most important of these agents are the hydrocoralline *Millipora alcicornis* and some encrusting bryozoa. Under the influence of both these agents the tissues of the gorgonian are disintegrated very slowly and the spicules set free a few at a time. While the *Millipora* will eventually cause the complete destruction of a colony the bryozoa were never found to extend for more than a few inches above the base of the colony. The actions of the two sorts of organisms is markedly different in that the Millipora causes the death of the gorgonian tissues by some chemical action and itself encrusts only the axial skeleton of the colony; while the bryozoa form a cylindrical tube surrounding the base of the gorgonian and cause the death of its tissues by the exclusion of food and oxygen.

There is no evidence that gorgonian colonies ever die from old age and to the agencies mentioned above is to be attributed the destruction of all those colonies the skeletons of which are found on the reefs. The fascies of the gorgonian fauna on any reef remains practically unchanged from year to year except for the introduction of the unusual factor of extensive destruction of the colonies by severe storms. The determination of the number of skeletons of dead colonies on any reef area will, therefore, afford the most practicable method of obtaining the death-rate of these organisms. This method unfortunately has the serious drawback that the results will always be too low because when the colonies are torn from their attachment on the reef by severe storms some of them will be carried so far from their original location that they will not be included in a count of skeletons on any given area. The percentage of axial skeletons to living colonies on a small reef where the entire number of colonies has been counted each year since 1910 has varied from 11.67% to 24.80% with an average of 17.22% for the six counts. On other reefs in the Tortugas region the destruction of gorgonians was nearly complete in the hurricane of October 17, 1910. In some restricted areas the amount of spicules set free from disintegrating gorgonian colonies was as much as 25 pounds to the square yard. On the basis of all the recorded observations it seems probable that, at a conservative estimate, about one-fifth of the gorgonian colonies on any reef area will be destroyed annually.

Since the fascies of the gorgonian fauna on the reefs remains relatively constant, and it is estimated that about one-fifth of the number of colonies are destroyed annually, it is important to determine the growth rate of the several species of these organisms which make up the most important elements in the gorgonian fauna.

Growth records for the species entering into this study have been kept for a period sufficiently long to cover the period from the time of their attachment as planulae to the attainment of the normal average size of the colony. The time necessary for this growth varies from two years (Gorgonia citrina), to five years (Gorgonia acerosa). The time necessary for any of these colonies to reach the average size falls well within the limit marked by the observed rate of destruction which would be necessary to maintain the constancy of the gorgonian fauna of any reef. Some few of these species appear to keep growing for an indefinite period after the medium size for the colony has been reached, but in such instances the growth is very slow after this time and would not greatly influence the general results.

TRANSFORMATIONS OF CONJUGATE SYSTEMS WITH EQUAL INVARIANTS

By Luther Pfahler Eisenhart

DEPARTMENT OF MATHEMATICS, PRINCETON UNIVERSITY

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Recently we considered at length two types of transformations of conjugate systems of curves on surfaces, which we called[1,2] *transformations K* and *transformations* Ω. It is the purpose of this note to show that there is a fundamental relation connecting these transformations.

If x, y, z are the cartesian coördinates of a surface S, referred to a conjugate system with equal point invariants, it is necessary and sufficient that x, y, z are solutions of an equation of the form

$$\frac{\partial^2\theta}{\partial u\partial v}+\frac{\partial \log\sqrt{\rho}}{\partial v}\frac{\partial\theta}{\partial u}+\frac{\log\sqrt{\rho}}{\partial u}\frac{\partial\theta}{\partial v}=0, \tag{1}$$

where ρ is a function of u and v in general. If θ_1 is any solution of (1) and λ_1 is the function defined by the consistent equations

$$\frac{\partial\lambda_1}{\partial u}=-\rho\frac{\partial\theta_1}{\partial u},\quad \frac{\partial\lambda_1}{\partial v}=\rho\frac{\partial\theta_1}{\partial v}, \tag{2}$$

the equations

$$\frac{\partial}{\partial u}(\lambda_1 x_1)=-\rho\left(x\frac{\partial\theta_1}{\partial u}-\theta_1\frac{\partial x}{\partial u}\right),\quad \frac{\partial}{\partial v}(\lambda_1 x_1)=\rho\left(x\frac{\partial\theta_1}{\partial v}-\theta_1\frac{\partial x}{\partial v}\right) \tag{3}$$

are consistent, and x_1 satisfies an equation of the form (1) when ρ is replaced by ρ_1, given by

$$\rho_1=\lambda_1^2\Big/\rho\theta_1^2. \tag{4}$$

The three functions x_1, y_1, z_1, given by (3) and similar equations in the y's and z's, are the cartesian coördinates of a surface S_1, which by definition is in the relation of a transformation K with the surface S. If M and M_1 are corresponding points on these surfaces, the developables of the congruence G of the lines MM_1 cut S and S_1 in the parametric curves and the focal points on the line MM_1 are harmonic to M and M_1. Conversely, when two surfaces S and S_1 are so related that the congruence of lines joining corresponding points meet S and S_1 in conjugate systems and the points of S and S_1 are harmonic to the focal points of the congruence, they are in the relation of a transformation K, as defined analytically by (3) [cf. M_1, p. 403].

Whenever any two surfaces are in a one-to-one correspondence such that the developables of the congruence of lines joining corresponding points cut the surfaces in conjugate systems, the lines of intersection of corresponding tangent planes to these surfaces form a congruence G' whose developables correspond to the developables of the former congruence.[3] Evidently two surfaces in the relation of a transformation K possess this property, but it is not a characteristic property.

When any surface S is subjected to a polar transformation with respect to a quadric, points and tangent planes are transformed into tangent planes and points respectively of the new surface Σ. Since straight lines go into straight lines, it is readily shown that conjugate directions on S go into conjugate directions on Σ. Also a congruence of lines is transformed into a congruence of lines, and the developable surfaces of the two congruences correspond; furthermore to the focal points on a line correspond the focal planes through the corresponding line of the other congruence.

We consider the effect of applying a polar transformation to two surfaces S and S_1 in the relation of a transformation K. If the new surfaces be denoted by Σ and Σ_1, the lines joining corresponding points $\overline{M}$ and $\overline{M}_1$ on these surfaces form a congruence $\overline{G}'$ whose developables meet Σ and Σ_1 in conjugate systems, and the tangent planes to Σ and Σ_1 meet in the lines of a congruence $\overline{G}$ whose developables correspond to the developables of the congruence $\overline{G}'$; moreover, the focal planes of the congruence $\overline{G}$ are harmonic to the tangent planes to Σ and Σ_1. These properties of the surfaces Σ and Σ_1 are possessed likewise by a pair of surfaces in the relation of a transformation[2] Ω. It is our purpose to show that Σ and Σ_1 are in the relation of a transformation Ω, and that the properties just mentioned are characteristic of transformations Ω.

The equation of any quadric may be put in the form

$$ax^2 + by^2 + cz^2 + 2dx + 2ey + 2fz + g = 0. \tag{5}$$

The equation of the polar plane of the point (x, y, z) with respect to this quadric is

$$Xx' + Yy' + Zz' = W. \tag{6}$$

where x', y', z' are the current rectangular coördinates and

$$X = \frac{ax+d}{\sqrt{\sigma}}, \quad Y = \frac{by+e}{\sqrt{\sigma}}, \quad Z = \frac{cz+f}{\sqrt{\sigma}}, \quad W = -\frac{dx+ey+fz+g}{\sqrt{\sigma}},$$

$$\sigma = (ax+d)^2 + (by+e)^2 + (cz+f)^2. \tag{7}$$

Hence X, Y, Z are the direction-cosines of the plane (6), and if x, y, z are the cartesian coördinates of a surface S, then X, Y, Z and W are the tangential coördinates of its transform Σ. These four coördinates are solutions of the equation

$$\frac{\partial^2\varphi}{\partial u\partial v}+\frac{\partial\log\sqrt[4]{\rho}}{\partial v}\frac{\partial\varphi}{\partial u}+\frac{\partial\log\sqrt{\rho}}{\partial u}\frac{\partial\varphi}{\partial v}+F\varphi=0, \tag{8}$$

where

$$\sqrt{\rho}=\sqrt{\rho\sigma},\quad F=\frac{1}{\sqrt{\sigma}}\frac{\partial^2\sqrt{\sigma}}{\partial u\partial v}+\frac{\partial\log\sqrt{\rho}}{\partial v}\frac{\partial\log\sqrt{\sigma}}{\partial u}+\frac{\partial\log\sqrt{\rho}}{\partial u}\frac{\partial\log\sqrt{\sigma}}{\partial v}. \tag{9}$$

Consequently the parametric conjugate system on Σ has equal tangential invariants.

When the same polar transformation is applied to S_1, the tangential coördinates of Σ_1, namely X_1, Y_1, Z_1, W_1, are obtained from (7) on replacing x, y, z by x_1, y_1, z_1 respectively. These functions satisfy an equation of the form (8), obtained on replacing ρ and F by ρ_1 and F_1, where in consequence of (4),

$$\sqrt{\rho_1}=-\lambda_1\sqrt{\sigma_1}\Big/\sqrt{\rho}\,\theta_1,\quad \sigma_1=(ax_1+d)^2+(by_1+e)^2+(cz_1+f)^2, \tag{10}$$

and F_1 is analogous to F.

Because of equations (3), the functions X_1, Y_1, Z_1, W_1 are the respective transforms of X, Y, Z, W by means of the equations

$$\frac{\partial}{\partial u}(\lambda_1\sqrt{\sigma_1}\varphi_1)=-\rho\sigma\left(\varphi\frac{\partial w_1}{\partial u}-w_1\frac{\partial\varphi}{\partial u}\right),\quad \frac{\partial}{\partial v}(\lambda_1\sqrt{\sigma_1}\varphi_1)=\rho\sigma\left(\varphi\frac{\partial w_1}{\partial v}-w_1\frac{\partial\varphi}{\partial v}\right), \tag{11}$$

where

$$w_1=\theta_1/\sqrt{\sigma}. \tag{12}$$

Consequently w_1 is a solution of (8). From (9) and (10) it follows that

$$\lambda_1\sqrt{\sigma_1}=-\sqrt{\rho\rho_1}\,w_1. \tag{13}$$

Hence equations (11) are equivalent to those of a transformation[2] Ω.

We are now in a position to prove the theorem:

If Σ and Σ_1 are so related that for the congruence of lines of intersection of corresponding tangent planes π and π_1 to Σ and Σ_1 respectively the focal planes of the congruence are harmonic to π and π_1, and the developables of the congruence correspond to conjugate systems on Σ and Σ_1, the latter systems have equal tangential invariants; and Σ and Σ_1 are in the relation of a transformation Ω. For if we apply the polar transformation to the surfaces Σ and Σ_1, the resulting surfaces are related in the manner which

we have stated to be characteristic of a transformation K. But as we have just shown, the surfaces Σ and Σ_1, being polar transforms of two surfaces in the relation of a transformation K, are themselves in the relation of a transformation Ω. Hence we have proved the above theorem and also the following:

When two surfaces S and S_1 are in the relation of a transformation K, their polar transforms are in the relation of a transformation Ω; and conversely.

Because of the dual relation between these two types of transformations, we are enabled to add to Theorems 4 and 6 of memoir M_1 the dual of the last part of the theorem of §4 of memoir M_2, and thus have the following theorem of permutability of the transformations K: *If S_1 and S_2 are two surfaces arising from S by transformations K, there can be found by quadratures an infinity of surfaces S', each of which is in the relation of transformations K with both S_1 and S_2. If M, M_1 and M_2 denote corresponding points on S, S_1 and S_2, the corresponding points M' on the surfaces S' lie on a line through M and in the plane π of the points M, M_1, M_2. The corresponding tangent planes to the surfaces S' envelope a quadric cone to which are tangent the tangent planes to S, S_1, S_2 at M, M_1, M_2. Moreover, the plane π touches its envelope at the point of intersection P of the lines MM' and M_1M_2; and the parametric curves on the envelope form a conjugate system whose tangents are harmonic to the lines MM' and M_1M_2, and contain the focal points of the lines MM_1, MM_2, $M'M_1$, $M'M_2$.* An analogous theorem of permutability of transformations Ω follows from the above in accordance with the principle of duality.

The relation between the two types of transformations is likewise helpful in interpreting the significance of certain evident forms of the transforming functions θ_1 and w_1. Thus we have shown (M_1, p. 401) that the necessary and sufficient condition that for two surfaces S and S_1 in the relation of a transformation K the corresponding tangent planes be parallel is that θ_1 be constant. In this case S and S_1 are associate surfaces, that is not only are the tangent planes parallel but also to asymptotic lines on either surface corresponds a conjugate system on the other. Moreover, any two associate surfaces are in this special kind of relation of a transformation K. Let S and S_1 be two associate surfaces and apply to them the polar transformation with respect to the quadric (5), where a, b, c are different from zero. Since corresponding tangent planes to S and S_1 meet in a line in the plane at infinity, the lines joining corresponding points on Σ and Σ_1 meet in a point—the pole of the plane at infinity with respect to the quadric. From (7)

it is seen that the coördinates of this point are $-d/a, -e/b, -f/c$. Conversely, if the lines joining corresponding points on two surfaces Σ and Σ_1, in the relation of a transformation Ω, meet in a point M, the surfaces S and S_1 arising from Σ and Σ_1 by a polar transformation are so placed that the lines of intersection of corresponding tangent planes to S and S_1 lie in a plane, the polar plane of M. When in particular, the fundamental quadric of the transformation is chosen so that M is the pole of the plane of infinity (which can always be done) S and S_1 are associate surfaces.

When θ_1 is a constant, it follows from (12) that w_1 is equal to $1/\sqrt{\sigma}$ to within a constant multiplier, which is unessential, as is evident from (11) and (13). From (7) we have

$$W+\frac{d}{a}X+\frac{e}{b}Y+\frac{f}{c}Z=\frac{1}{\sqrt{\sigma}}\left(\frac{d^2}{a}+\frac{e^2}{b}+\frac{f^2}{c}-g\right). \qquad (14)$$

We choose the quadric so that the coefficient in (14) of $1/\sqrt{\sigma}$ is not equal to zero. Hence w_1 is a homogeneous linear function of X, Y, Z and W, when the lines joining corresponding points on Σ and Σ_1 are concurrent. Conversely, suppose that w_1 is a homogeneous linear function of the form of the left-hand member of (14). Apply to Σ the polar transformation with respect to the quadric (5) and let S be the transform of Σ. Take an associate surface of S, say S_1. When now the transformation with respect to the quadric (5) is applied to S_1, we get a surface Σ_1 in the relation of a transformation Ω to Σ, the function w_1 differing by a constant factor at most from the left-hand member of (14). Combining this result with the observations made in the preceding paragraph, we have the theorem:

When the function w_1 determining a transformation Ω of a surface Σ is equal to W plus a homogeneous linear function of the direction-cosines of the normal to Σ, ths lines joining corresponding points on Σ and its transform Σ_1 are concurrent; and conversely.

If in (5) we put $c = 0$, we have in place of (14) the equation $Z = f/\sqrt{\sigma}$. Consequently w_1 differs from Z by a constant factor at most, which is unessential. Since the z coördinate of the plane at infinity with respect to the quadric (5) is infinite, the lines joining corresponding points on Σ and Σ_1 are parallel. By reasoning analogous to the preceding we arrive at the theorem:

When the function w_1 determining a transformation Ω of a surface Σ is a homogeneous linear function of the direction-cosines of the normal to Σ, the lines joining the points on Σ and its transform Σ_1 are parallel; and conversely.

If θ_1 is a linear function of x, y, z, it is possible to choose the quadric (5) so that by means of (7) and (14) $\theta_1/\sqrt{\sigma}$ is expressible as a homogeneous linear function of X, Y, Z, W, involving W at least. Hence:

When the function θ_1 determining a transformation K of a surface S is a linear function of the cartesian coördinates of S, the corresponding tangent planes to S and its transform meet in line of a fixed plane.

[1] Transformations of conjugate systems with equal point invariants, *Trans. Amer. Math. Soc.*, 15, 397–430 (1914). This will be referred to as memoir M_1.

[2] Conjugate systems with equal tangential invariants and the transformation of Moutard, *Palermo, Rend. Circ. Mat.*, 39, (1915). This will be referred to as memoir M_2.

[3] Guichard, *Ann. sci. Ec. norm., Paris*, Ser. 3, 14, 492 (1897).

ON THE POLE EFFECT IN THE IRON ARC

By Charles E. St. John and Harold D. Babcock

MOUNT WILSON SOLAR OBSERVATORY, CARNEGIE INSTITUTION OF WASHINGTON

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In a communication to the Academy which appeared in the PROCEEDINGS for March 1915, we reported some results of our investigations on the pole effect in the iron arc under normal conditions. We have found between two and three hundred lines whose wave-lengths at the negative pole are distinctly longer than when the light is taken from a cross section at the center of the arc.

Aside from the theoretical interest in such changes in wave-length, reference may be made to the following points:

1. A number of these lines are included among the international standards of the second order. Their wave-lengths depend upon interferometer measurements made by three independent observers, the means of which have been adopted as standards by the International Union for Coöperation in Solar Research.

2. There is a region of the iron spectrum extending from λ 5500 to λ 6000 in which no other class of lines is available for standards.

3. In various laboratories there are in progress redeterminations, based upon the iron standards, of the wave-lengths in international units of the lines of many elements. In these redeterminations the instrument most frequently used is the concave grating in the usual Rowland mounting. In ordinary practice, the slit of the spectrograph is parallel to the axis of the arc and includes the major portion of its length. We have found that the pole effect appears at a considerable distance from the negative pole and that for high precision

the light should not be taken from a point less than 2 mm. from the pole of the arc. The astigmatism of the concave grating in the usual mounting introduces more or less pole effect and to that degree vitiates results involving the lines under consideration. The practice of reversing the current in the arc in order to overcome the tendency to produce wedge-shaped lines, when the slit and the axis of the arc are parallel, obscures but does not eliminate the pole effect. Since the redeterminations aim at a precision of 0.002 to 0.003 angstrom, it is important to take the pole effect into consideration.

4. Lines of the type considered are not limited to iron but occur in the spectra of other elements, the detailed investigation of which is necessary before safe deductions can be made from their use in astrophysical investigations.

Bearing upon the explanation of the pole effect, our recent investigations yield the following results. The absence of a general increase in pressure at the negative pole, evidenced by the unchanged wavelength of whole classes of lines known to be affected by pressure, led us to suggest an increased density of the radiating vapor as a possible cause, but our measurements of furnace spectra taken with a 10 fold increase in the quantity of iron vaporized show no change of wavelength for these lines. Furthermore, the lines of manganese appearing as an impurity in the iron poles show displacements of the same order as neighboring iron lines; it is difficult to imagine a high density, even at the pole, for manganese vapor appearing only as a trace.

The effect of temperature was examined by comparing the wavelengths of these lines at temperatures as widely different as is practicable in the furnace (2100°–2600°C.). No evidence was found of any dependence of wave-length upon temperature.

As the result of a study of the behavior of these lines in an arc *in vacuo*, it was found that the pole effect in general does not occur at pressures below 10 cm. of mercury. The arc which we employ *in vacuo* is of the same type and length and carries the same current as that used at normal pressure, but in appearance it is strikingly different. Under normal pressure the vapor mainly concerned in the production of these lines issues from a point source on the electrode, is highly luminous and is confined to a comparatively limited volume; *in vacuo* the luminosity covers the entire surface of the pole more uniformly and is much less intense, while definite structure is for the most part lacking. The disappearance of the pole effect indicates that the electrical conditions play a subordinate rôle, if any, in producing the displacements, but a more definitive investigation is about to be undertaken

In view of the absence of a general increase in pressure at the negative pole, it is probable that some agency other than pressure is involved, but there is the possibility of a local increase in pressure affecting only the innermost portion of the vapor in the vicinity of the pole. To obtain light upon this point, a determination of the pressure shift per atmosphere has been made for a large number of the lines under consideration. Their wave-lengths *in vacuo* and at normal pressure have been compared, the light in each case being taken from the central section of the arc. These conditions are well suited to a measurement of the pressure shift for lines of this type, as they are of good quality in both spectra. In a paper by St. John and Ware[1] they said:

> Neither the small pressure-changes of about one-fifth of an atmosphere taken advantage of in this investigation, nor the high pressures used by Gale and Adams are well adapted to the study of lines of this type, and it is purposed to examine *in vacuo* and under normal pressure the behavior of an extended list of lines belonging to groups *d* and *e*.

If the pole effect is due to pressure alone, the connection between it and wave-length should be similar to that relating pressure shift and wave-length. A brief summary of our results is given in the accompanying table.

POLE EFFECT AND PRESSURE SHIFT RELATIVE TO WAVE-LENGTH

Group	*No. of Lines*	*Mean* λ	*Pressure Shift per Atm.*	*Pole Effect*
d	25	4085.14	+0.0048A	+0.0096A
c5	16	4766.41	+0.0093	+0.0119
d	12	5528.44	+0.0089	+0.0206
d	5	6350.74	+0.0160	+0.0185

The three sections of group *d* show pressure displacements which vary as the cube of the wave-length, a result in harmony with the observations of Gale and Adams.[2] On the other hand there is no relation apparent between pole effect and wave-length. If we attempt to determine the difference in pressure between the center of the arc and a point in the core near the negative electrode by comparing the last two columns in the table, we find 2.0; 1.3; 2.3; and 1.1 atmospheres, numbers whose discrepancies exceed the errors of observation. Such a treatment of the data assumes that the pressure in the core of the arc at the negative pole is the same for all wave-lengths. The increase of pressure, if it exists, must be produced by rapid vaporization and the almost explosive expulsion of the emission centers, which are not necessarily the same for all wave-lengths. Investigations are now to be undertaken in order to obtain some measure of the velocities of the emitting particles.

Summary. 1. Emphasis has been placed upon the necessity of considering the pole effect in the redetermination of wave-lengths in international units.

2. The wave-lengths of these sensitive lines are not affected by a wide variation of density of the radiating vapor.

3. Their wave-lengths are independent of changes in temperature over the range of our observations.

4. For the lines considered the pole effect does not occur *in vacuo*, and in so far appears independent of electrical conditions.

5. The observed pole effect does not vary with wave-length in the same way as pressure shift, and cannot be explained as a pure pressure effect unless the pressure changes in certain definite ways with the wave-length.

[1] *Mt. Wilson Contr.* No. 61; *Astrophys. J.* 36, 37 (1912).
[2] *Mt. Wilson Contr.* No. 58; *Astrophys. J.* 35, 10 (1912).

INHERITANCE IN THE ASEXUAL REPRODUCTION OF HYDRA VIRIDIS

By K. S. Lashley

ZOOLOGICAL LABORATORY, JOHNS HOPKINS UNIVERSITY

Presented to the Academy, March 17, 1915

Do heritable variations commonly occur among the offspring of a single individual multiplying asexually? May selection among such offspring produce strains differing in hereditary characters? The investigation here resumed is designed to contribute data toward the answer to these much debated questions.

A number of specimens of Hydra viridis, taken at random from wild populations, gave rise by asexual reproduction to clones differing from one another in their average number of tentacles and in other characters. As a test of whether such differences are the result of internal factors or of environmental differences two clones were bred in large numbers for a period of five months, during which time the members of the two clones were kept under environmental conditions as nearly as possible the same. Each polyp was kept in a separate culture dish and food was distributed uniformly to all. The number of tentacles was recorded at the time when the polyps began their independent life after separation from the parents (the initial number of tentacles), and records were kept, also, of changes in the number of tentacles of parents.

The two clones kept under parallel conditions gave the following results. The average number of tentacles of 1353 members of one

clone (A) bred during the first three months was 6.463 ± 0.013; the average number of tentacles of 1395 members of the other (D) was 5.793 ± 0.011; the difference between these averages is 0.724 ± 0.017. At the end of three months a single polyp was taken from each clone and used to found another clone. The average number of tentacles of the subordinate clone obtained in this way from clone A was 6.907 ± 0.026; that of the clone derived from D was 5.844 ± 0.029; the difference is 1.063 ± 0.039, in the same direction as before. At different times during the history of the clones the number of tentacles of the buds fluctuated considerably but the difference between the averages of the buds produced at the same time by the two remained fairly constant. The minimum difference in any one week of cultivation was 0.449 ± 0.042, the maximum difference, 1.063 ± 0.039. Small groups of polyps from the two clones were kept in mass cultures under partly controlled environmental conditions, such as reduced food supply. Under such conditions the difference persisted so long as the two clones were kept under the same environment.

These clones differed in other respects besides the average number of tentacles. The polyps of clone A were, on the average, more than twice as large as those of clone D, the average for the two being: A = 0.869 ± 0.021 cu. mm., D = 0.322 ± 0.022 cu. mm: the average difference is 0.547 ± 0.023 cu. mm. Polyps of clone A began to produce buds at an average age of 3.74 ± 0.074 days, those of clone D at 4.81 ± 0.10 days; a difference of 1.06 ± 0.13 days in the average age at reproductive maturity.

At no time during their history did the two clones show an identity of characters. There were no constant differences in the environmental conditions under which they were cultivated and it is certain that the differences between the clones were the result of some internal factors. The clones represented hereditarily diverse races. Other diverse races showing somewhat less well marked differences have been found and seem to be of rather frequent occurrence in wild populations. No direct evidence upon the origin of such diverse races or their relation to sexual reproduction has been obtained.

The inheritance of variations in the number of tentacles within the clone was studied by statistical methods and by the continued selection of variates. A comparison of the variations in the initial number of tentacles of parent and offspring by the use of the coefficient of correlation shows no significant resemblance between parent and offspring. The coefficients obtained are such as the following:

No. of Parents	No. of Offspring	Coefficient of Correlation
251	1395	0.0038 ± 0.018
78	439	−0.0342 ± 0.032
164	859	0.0011 ± 0.023
28	204	0.0314 ± 0.047
18	153	−0.2420 ± 0.051
51	154	−0.0750 ± 0.054

As is well known, the number of tentacles of Hydra changes during the life of the individual. When the number of tentacles of each bud is compared with the number born by the parent at the time when the bud was produced there is a slight correlation in the variations of parents and offspring. For the first clone recorded above this is 0.096 ± 0.016. There is also a slight positive correlation in the variations of the buds produced by a single parent, as is shown by the following:

No. of Pairings	Fraternal Coefficient of Correlation
12099	0.161 ± 0.004
10766	0.077 ± 0.006

A study of the relation of variations in the number of tentacles to environmental changes shows that unfavorable conditions tend to reduce, or to prevent increase in, the number of tentacles of parents and at the same time lead to a reduction in the number of tentacles of the offspring of these parents. Thus, wherever diversities of environment occur in cultures of Hydra there should be produced a likeness between parent and offspring that is not the result of heredity. To test this, the period of cultivation of the two clones giving the above fraternal correlations was divided arbitrarily into five-day periods and the buds produced within each of these periods were compared. From this comparison it appears that unrelated buds produced under like conditions of cultivation resemble each other as much as do the offspring from a single parent. The coefficients of correlation between the unrelated buds produced at the same time were:

No. of Pairings	Coefficient of Correlation
95141	0.0774 ± 0.0015
101872	0.1313 ± 0.0014

It thus appears that the slight resemblance found between parent and offspring and between members of the same fraternity within the clone may be due either to an inheritance of variations or to the like action of environment upon individuals produced at nearly the same time. Statistical methods do not suffice to distinguish between the two possibilities.

Twenty-five variates from a single clone were selected for seven or more tentacles, and 25 for six or less, the mean of the clone lying between six and seven. Selection was continued for six or more generations. At the end of this time records were kept of all buds produced by the last selected generation. Those produced by parents from the series selected for few tentacles were found to have somewhat fewer tentacles than those from parents of the other series, but the difference appeared only in the first six buds and did not persist in the later buds produced by the same parents. The average number of tentacles of the first six and of later buds produced by the last selected generation is shown in the following table.

Buds of the Last Selected Generation

	AVERAGE OF ALL	FIRST SIX	LATER BUDS
Selected for many tentacles	6.695 ± 0.023	6.677 ± 0.029	6.712 ± 0.030
Selected for few tentacles	6.605 ± 0.026	6.460 ± 0.034	6.782 ± 0.037
Difference	0.095 ± 0.035	0.217 ± 0.044	−0.070 ± 0.047

Continued selection at first seemed to have produced a change in the hereditary character of the two groups but this did not persist even through a single generation. Complete regression appeared as soon as the polyps reached maturity.

An almost identical result was obtained in an earlier experiment on the effects of injury. Polyps which had regenerated the mouth and tentacles showed a marked reduction in the number of tentacles of the buds which they produced immediately after regeneration, but the average number of tentacles of successive buds formed after regeneration increased until at the end of two weeks, when four to eight buds had been produced, the polyps had returned to the normal condition of the clone from which they were derived.

The similarity of these results makes it certain that the only effect of selection was a temporary change in the vigor of the selected polyps (the selection of individuals with few tentacles involving the selection of weaker polyps) and that there is no cumulative inheritance of variations in the number of tentacles within the clone. Races of Hydra differing in their hereditary number of tentacles exist but individual variations do not involve changes in the hereditary constitution of such races.

Some evidence that the same conclusions apply to the inheritance of size was obtained, but the relation of variations in size to environmental changes has not been investigated thoroughly.

ON THE MONTICELLITE-LIKE MINERAL IN METEORITES, AND ON OLDHAMITE AS A METEORIC CONSTITUENT*

By George P. Merrill

DEPARTMENT OF GEOLOGY, UNITED STATES NATIONAL MUSEUM, WASHINGTON

Presented to the Academy, March 23, 1915

It may be remembered that in 1883 Tschermak[1] mentioned the occurrence in many chondritic meteorites of an almost colorless constituent occurring with very irregular outlines, in the groundmass, and exceeding in size the prevailing granules. These showed only traces of cleavages, were doubly refracting and optically biaxial though never showing good interference figures. The polarization colors were weak. It was found impossible to determine absolutely the mineral nature of the constituent, but it was suggested that it might be monticellite. Its presence was noted in the Alfianello, Mocs, Knyahinya, and Mezo Madaras stones. The occurrence in the Knyahinya stone was later figured by him on plate 14, figure 3, of his *Die Microskopische Beschaffenheit der Meteoriten*. Since Tschermak's writing the mineral has been noted by various authors. Lacroix[2] describes in some detail what is unquestionably the same mineral in the stone of St. Christophe la Chartreuse. He finds it possessing two easy but interrupted cleavages, cutting at an angle of about 60°, with a birefringence less than 0.003, which he notes is less than that of olivine and superior to that of feldspar, with which it is often found in contact. He also was unable to determine its exact nature optically, or to separate it by means of heavy solution, but noted that it could not be monticellite on account of its low birefringence. He further noted its occurrence in the meteorites of Chantonnay, d'Aumale, de Barbotan, de Salles, de Berlanguillas, and Lancon. The present writer recognized the same mineral in sections of the meteorites from Rich Mountain, N. C.,[3] and Felix, Alabama,[4] and though recognizing its biaxial nature and weak birefringence was likewise unable to identify it absolutely. Still later, Borgström recognized it in the meteorite of St. Michel,[5] and was able to determine the positive character of the acute bisectrix.

In connection with his work on the minor constituents of meteorites, the present writer had opportunity for examining numerous occurrences of the mineral, and it was decided if possible to determine its nature or at least to carry a knowledge of its properties one step farther. Unable by the means at his command to fully satisfy himself regarding all its

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optical properties further than given in the paper referred to above, sections of both the Alfianello and Rich Mountain stones were submitted to Dr. F. E. Wright of the Geophysical Laboratory, who reported the mineral to be weakly birefracting with interference colors not exceeding gray white of the first order, and the refractive indices of which were $\alpha = 1.623 \pm 0.002$ and $\gamma = 1.627 \pm 0.002$, the birefringence being less than 0.005. He also verified previous determinations of its biaxial and doubtfully positive character. With these additional data at hand reference was made to E. S. Larsen's tables,[6] where it was found that the only known mineral possessing the properties found by the various observers was the phosphate *francolite*, which is reported, however, as optically negative. Nevertheless, with this much for a guide, an attempt was then made at ascertaining its chemical nature. The small size of the particles and their sporadic occurrence rendered it impossible to isolate them either by heavy solution or by an electro-magnet. Recourse was then made to micro-chemical methods. After repeated trials, a small particle, less than 0.5 mm. in diameter, was removed from an uncovered section of the Alfianello stone, and transferred to a clean slide where it was covered with a drop of strong hydrochloric acid and allowed to stand over night, during which time the acid evaporated to dryness. On taking it up again in a fresh drop of acid the mineral was found to have been strongly attacked though not completely dissolved. A drop of the solution was then transferred to still another slide and placed in contact with a drop of sulphuric acid. Abundant acicular and plumose crystals of gypsum shortly began to make their appearance around the margin of the drop. The liquid remaining on the first slide was then evaporated to dryness over an alcohol lamp and the residue taken up with nitric acid, a drop of ammonium molybdate solution added, and the slide slightly warmed on the steam radiator for a few moments, when abundant characteristic globules of the phospho-molybdate of ammonium separated out. As checks upon this, independent tests were made in slides from the Alfianello, Dhurmsala, Felix, Mocs, and Rich Mountain, meteorites by painting around the mineral with vaseline and treating the exposed portion with a drop of nitric acid. The mineral was found to be completely and easily soluble in this acid and in all cases results confirmatory of the first were obtained. It may be added that the solution in nitric acid goes on so rapidly that its progress may readily be observed under the microscope. In making this test, nitric acid has the advantage in that it does not so readily attack the olivine and there is hence no trouble from the obscuring reactions by gelatinous silica. The tests for other constituents, such as alumina,

yielded no satisfactory returns. As a last resort a 12-gram fragment of the Alfianello stone was submitted to Dr. Whitfield with the request that it be pulverized, and, after removal of the metallic portion, boiled in water to remove any possible oldhamite or its alteration products, and the residue then boiled in dilute hydrochloric acid. Disregarding as a matter of necessity the iron and magnesia which might come from the olivine, the results obtained were as follows: The water solution yielded 0.03% CaO and 0.013% S, the equivalent of 0.030% CaS, or oldhamite. The acid solution yielded 0.344% CaO and 0.08% P_2O_5, with traces of alumina.

Satisfactory results from such tests could scarcely be anticipated but are nevertheless not without interest. It will be recalled that the ratio of CaO to P_2O_5 in francolite as given by Schaller[7] is 10 to 3. The results obtained by Whitfield by the method described were 9 to 2.

The accompanying figures, drawn free hand, directly from the thin sections, will serve to give an idea of the general appearance and optical properties of the mineral. No attempt has been made to outline other of the constituents excepting where noted as enclosures. The actual size of the largest forms, as those of Alfianello and Rich Mountain (figs. 1 and 2), is not above 0.5 mm. in diameter. In figure 1, from a slide of the Alfianello stone, the mineral in question, left colorless and unshaded, is traversed by wavy cracks or cleavage lines extending rom the upper right to the lower left. The dotted areas are olivine and those with broken parallel lines at the right are enstatite. The completely black are metal and metallic sulphide. In the upper portion the mineral reaches its maximum extinction n the position indicated by the cross. In the lower right, which remains almost completely dark during an entire revolution of the stage, there appears an indistinct, slightly curved black bar, indicating the emergence of an optic axis of a biaxial mineral.

Figure 2, from a slide of the Rich Mountain stone, shows likewise a characteristic occurrence, with near the center an enclosure of olivine and other scattered enclosures of the same mineral and metallic particles. The entire area extinguishes as a unit and in the position indicated by the cross, though the lower portion shows indications of two cleavages and an indistinct black brush sweeps across the field as the stage is revolved between crossed nicols with the occular removed.

Figures 3 and 4 show the same mineral in the Pultusk and Dhurmsala stones, respectively. The position of maximum extinction is again shown by the black cross. In figure 4, which extinguishes as a unit, two easy but interrupted cleavages are very evident at the left and bot-

Fig. 1

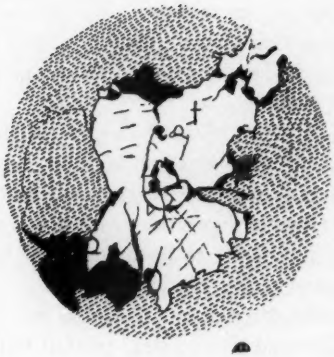


Fig. 2

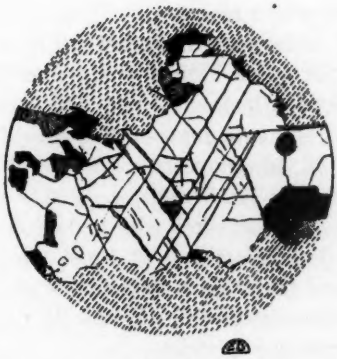


Fig. 5

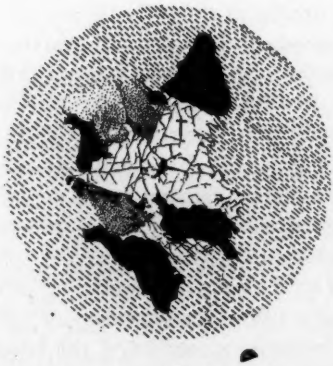


Fig. 3

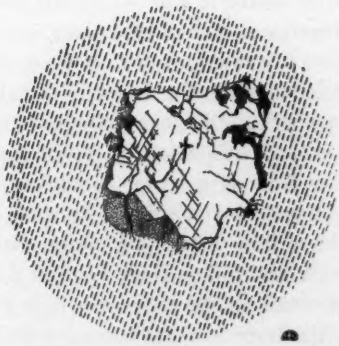


Fig. 4

tom of the section. No satisfactory interference figure is obtainable from this section, though a very indistinct dark brush sweeping across the field indicates that the plane of the optic axes cuts the obtuse angle of cleavage.

In figure 5 is shown an occurrence in the Mocs stone concerning which there was considerable doubt, not merely on account of the perfection of the cleavage but from the fact that it showed an indistinct interference figure in which the axial angle was so small that it was at first thought to be uniaxial: it was, moreover, optically negative, and more nearly resembles normal apatite than do the other occurrences under discussion. To settle the matter the cover was removed from the slide and the mineral treated with a drop of nitric acid as in previous cases. Within an hour from the time the drop was applied the mineral was entirely eaten out and the solution, as before, yielded lime and phosphoric acid, with the proper reagents.

The accumulated determinative characteristics of the doubtful mineral so far as made out by the various workers are then as follows:

Colorless, with but few inclosures, two cleavages, imperfect and interrupted, cutting at an acute angle of 60°; optically biaxial and positive (?), with large 2E; birefringence weak, less than 0.005, refractive indices, as determined by Dr. Wright, $\alpha = 1.623 \pm 0.002$ and $\gamma = 1.627 \pm 0.002$; no pleochroism, and often with undulatory extinction; polarization in light and dark colors and at times almost completely dark during a revolution of the stage between cross nicols; easily soluble in cold nitric acid, giving solutions reacting for lime and phosphoric acid; very brittle and occurrence sporadic.

There is apparently no question then but that we have a heretofore unrecognized form of mineral phosphate as a fairly common constituent of meteoric stones. From normal apatite it differs in its low birefringence as well as cleavage and general optical characters. From francolite it would appear to differ in that so far as determined it is optically positive, while the latter is negative. Just how much weight is to be attached to this last characteristic, is yet to be determined. One has a natural hesitation in relegating it to francolite for genetic reasons, since francolite, so far as known, is a secondary mineral and a deposit from aqueous solution. It is to be noted, however, that the mineral I have been describing occurs with outlines suggestive of its secondary origin and filling drusy cavities formed at the time of the original consolidation of the stone in which it occurs. Whether secondary or not, as the term is usually employed, it is certainly a product of the latest period of crystallization. Until the material can be found in such quan-

tity as to be available for chemical analysis, apparently this is the best that can be done. Attention may, however, be called to the fact that phosphorous in the form of apatite has thus far been definitely recognized in meteorites only by Berwerth,[8] although a small amount of phosphorous is almost invariably reported either as P or P_2O_5 from the soluble (silicate) portion of the stony meteorites. It would seem probable, therefore, that this soluble salt is not in the form of apatite but that rather it owes its presence to the monticellite-like mineral which is now relegated doubtfully to the species francolite.

On the assumption that the doubtfully monticellite-like mineral referred to by the various workers is in all cases to be relegated to the same species, it has now been recognized in the stones listed below.

Alfianello,	Chantonnay,	Lancon,	Rich Mountain,
Aumale,	Dhurmsala,	Mezo Madaras,	Saint Christophe,
Barbotan,	Felix,	Mocs,	Saint Michel,
Berlanguillas,	Knyahinya,	Pultusk,	Salles.

OLDHAMITE AS A METEORIC CONSTITUENT

The presence of the calcium sulphide oldhamite in a meteorite was first made known by Maskelyne who found it in granules macroscopically developed in the Busti stone.[9] He also noted its probable presence in that of Bishopville, and suggested an even wider distribution. Since Maskelyne's writing but few new occurrences have been noted, though its probable presence has been more than once suggested. The present writer found a lime salt soluble in water in the Morristown meteorite which he surmised might be gypsum, resulting from the alteration of the sulphide.[10] He also found abundant chemical evidence of its one-time presence in the stone of Cullison,[11] and was able to verify Lacroix's microscopic determination of its presence in the Indarch stone.[12] Borgström has also shown its presence in the stone from Hvittis,[13] Cohen in that of St. Marks,[14] and Tassin by chemical tests has pointed out its probable occurrence in that of Allegan.[15]

These facts, considered in connection with my work on the minor constituents of meteorites, have led me to make a most careful search for the mineral, but with the exception of that of Indarch none of the stones examined have yielded absolute ocular proof of its occurrence. The known solubility of the mineral in water has, however, afforded opportunity for a safe presumption regarding its presence or absence.

Quantities of a gram or more from each of the stones listed below were finely pulverized and boiled for an hour or so in distilled water, the solutions then filtered and tested for lime with ammonium oxalate.

In alphabetical order the stones tested are as follows:

Alfianello, positive lime reaction
Beaver Creek, negative lime reaction
Bishopville, positive lime reaction
Cullison, positive lime reaction
Dhurmsala, positive lime reaction
Dores dos Campos, positive lime reaction
Estherville, positive lime reaction
Farmington, faint positive lime reaction
Fayette, positive lime reaction
Felix, positive lime reaction
Forest City, positive lime reaction
Hessle, faint positive lime reaction
Holbrook, positive lime reaction
Homestead, positive lime reaction
Knyahinya, negative lime reaction
L'Aigle, positive lime reaction
Mocs, positive lime reaction
Monroe, negative lime reaction
New Concord, doubtful lime reaction
Parnallee, faint positive lime reaction
Pultusk, positive lime reaction
Quenggouk, positive lime reaction
Tennasilm, positive lime reaction

The mere presence of a soluble calcium compound does not necessarily prove the presence of oldhamite, but in cases where the boiling is accompanied by a liberation of H_2S, it would seem safe to assume its presence in this form, and in the cases of the stones of Alfianello, Bishopville, and Indarch we have been able from the lime in the water solution to calculate its approximate percentage amount.

That the mineral occurs more or less sporadically is suggested by Maskelyne's figure and description of the Busti stone, and has been demonstrated by our own researches, certain individuals from the Pultusk fall giving abundant indications of its presence, while others gave no sign. It is evident, however, that the mineral is a common and widespread constituent, and the examination of no stone meteorite should be regarded as complete unless it has been sought for by both optical and chemical means. A failure to find it in thin sections may be due to the breaking out of the granules in the process of grinding, or more likely, particularly in the case of stones that have lain long in the ground, to its having undergone alteration into an earthy, gypseous, and quite unrecognizable product.

[1] *Sitz. Wien. Akad.*, **88**, No. 1, p. 355 (1883).
[2] *Bull. Soc. Sci. Nat. Ouest*, ser. 2, **6**, 81–112 (1906).
[3] *Proc. U. S. Nat. Mus.*, **32**, 243 (1907).
[4] Ibid., **24**, 196 (1901).
[5] *Bull. de la Com. Geol. de Finlande*, No. 34, 1912, p. 43.
[6] *Indices of Refraction of Minerals*, in MS.
[7] *Bulletin* 509, *U. S. Geol. Survey*, p. 599.
[8] *Min. u. Pet. Mittheil.*, **25**, 188 (1906).
[9] *Phil. Trans. R. Soc. London*, **160**, 189–214 (1870).
[10] *Amer. J. Sci.*, **11**, 149 (1896).
[11] *Proc. U. S. Nat. Mus.*, **44**, 330 (1913).
[12] *Proc. U. S. Nat. Mus.*, 1915.
[13] *Die Meteoriten von Hvittis in Marjalahti*, 1903.
[14] *Ann. S. African Mus.*, **5**, 1–16 (1906).
[15] *Proc. U. S. Nat. Mus.*, **34**, 433 (1908).

ABSOLUTE SCALES OF PHOTOGRAPHIC AND PHOTOVISUAL MAGNITUDE

By Frederick H. Seares

MOUNT WILSON SOLAR OBSERVATORY, CARNEGIE INSTITUTION OF WASHINGTON

Presented to the Academy, April 14, 1915

The first extensive photometric investigation undertaken with the 60-inch reflector has been the determination of absolute scales of photographic and photovisual magnitude for stars near the North Pole. Although the instrument is best adapted for the observation of objects fainter than the tenth magnitude, it can also be used for the brighter stars; and it thus becomes possible to secure, on a uniform system of color, results covering the entire range of stellar brightness at present known.

In any photometric problem involving the use of photographic methods, there is serious difficulty in evaluating the functional relation connecting the intensity of the light acting on the plate with the observed photographic effect. The photographic process is too complicated and too sensitive to slight fluctuations in the conditions which determine its action to permit of the application of anything like a general relation; and it is necessary to standardize or calibrate the images appearing on each plate which is to contribute toward an absolute scale.

Besides photographic difficulties, there is another which is serious, namely, that encountered in all physical observations involving the comparison of quantities which, relatively, are very large and very small. In the present case, the range of brightness actually covered in the determination of the photographic scale is about $17\frac{1}{2}$ mags.; the intensity ratio for the brightest and the faintest of the stars observed is therefore of the order of 1 to 10,000,000, and consequently the opportunity for an accumulation of error in passing from the one extreme of brightness to the other is great.

The methods commonly employed for the standardization of the photographic effect in terms of intensity have as their principle the production of two series of images with a known variation of the intensity between the exposures. This in itself is not easily accomplished, at least with assurance of freedom from systematic error. A variation of the total energy by a change in the exposure time immediately introduces the photographic difficulties that we wish to avoid; a change in the intensity by a reduction of the aperture changes the diffraction pattern of the optical image, and it is not a priori certain

that the same quantity of energy distributed over different patterns produces the same photographic result; the use of a coarse objective grating or screen of wire gauze is unobjectionable from the standpoint of diffraction, but requires a troublesome laboratory investigation for the determination of its constant; the diversion of a certain fraction of the light into a secondary image by means of a prism of small angle is subject to disturbances by diffraction and absorption. Other methods are subject to similar uncertainties; and, in addition, all which involve successive exposures upon the same plate, like the majority of those just enumerated, have to contend with irregularities in the atmospheric conditions.

In arranging the program of observations it was considered that the latter could be disregarded, because of the favorable situation of Mount Wilson and the moderate exposure times which would be required. Moreover, the considerable accumulation of material necessary for the investigation would render atmospheric disturbances wholly accidental. Other difficulties, it was hoped, would be sufficiently controlled by the use of a wire gauze screen and a series of circular diaphragms covering a wide range of aperture. For the latter, the following diameters in inches were adopted: 40, 32, 14, 9, 8, and 6. Two large screens of wire gauze were used, one of single thickness and one of double thickness, the wires of the latter being crossed at an angle of 45°; smaller screens for use over the diaphragms of 14 inches and less were also available. The constants depend upon laboratory determinations of the absorption for point sources, controlled by the measurement of the absorption for surfaces.

It was found convenient to separate the investigation into three parts, with a corresponding variation in the treatment: (*a*) bright stars, including objects brighter than the tenth magnitude; (*b*) intermediate stars, from the tenth to the eighteenth magnitude; (*c*) faint stars, fainter than the eighteenth magnitude. The limits refer to the photographic scale.

For both scales the work was begun with the second group—the intermediate stars. The details of observation, measurement, and reduction have been described elsewhere.[1] For the photographic scale, to which the following paragraphs refer, the exposure times fall into two groups, one of 11 minutes or less, the other ranging between 30 minutes and 60 minutes. Forty-two separate determinations of the scale were derived from the data on 15 plates of shorter exposure; from those of longer exposure there were fourteen determinations, from an equal number of plates. The former series involved the use of the

single-thickness screen, 60 inches in diameter, and the 32, 14, 8, and 6-inch diaphragms, besides two other arrangements of less importance.

For the interval 10.5–17.6, the mean of 17 scales with the 32-inch diaphragm is practically identical with that of 10 found with the 14-inch diaphragm. The 5 scales with the two smaller diaphragms show a deviation of about 1% from the mean of all, and there is a similar divergence between the results for the wire gauze screen and the mean for all the diaphragms. The agreement is therefore such as to leave little doubt as to the negligible character of the diffraction effect and the satisfactory elimination of other errors.

The longer exposure plates, which in several cases reach the nineteenth magnitude, were all obtained with diaphragms of either 32 or 14 inches, and are likewise satisfactorily accordant. These plates also give results for the brightest of the intermediate stars; in other words, they overlap completely the region covered by the plates of shorter exposure. The average difference between the mean scales from the two series, derived from nine groups of stars between 10.6 and 16.8, is 0.015 mag. There seem, therefore, to be no systematic errors which depend upon the exposure time.

The determination of the scale for the two remaining groups—faint stars and bright stars—presupposes a knowledge of that for the intermediate group. Here again the methods have been fully described elsewhere,[2] and only a very brief statement need be included here.

The extension to the fainter objects was by means of plates which, with one exception, received two exposures, both with the full aperture of 60 inches, but with different exposure times; the longer exposure was four or five hours, the shorter approximately half an hour. The reduction was based upon the empirical relation established by Kron,[3] which expresses the law of photographic action. Strictly speaking, the process involves an extrapolation, but one which is fairly reliable. The accordance of the six plates for the faint stars is scarcely less satisfactory than that of the long-exposure diaphragm plates used for the intermediate stars. The limiting photographic magnitude thus reached is about 20, which may be taken as the faintest attainable, under favorable conditions, with an exposure of four hours.

Owing to the small field of the reflector, and the relatively wide distribution of the bright stars, these objects had generally to be observed individually. They were photographed with screens or diaphragms producing images comparable with those of stars between the tenth and fifteenth magnitudes, obtained with the same exposure but without screen or diaphragm. The following is a typical arrangement of the exposures,

which were 2 minutes each: (1) intermediate stars, full aperture; (2) bright star with reduction of intensity, usually three or four exposures with different arrangements of diaphragms and screens; (3) intermediate stars, full aperture. The magnitudes of the reduced-intensity images were found by comparison with those of the intermediate stars, which had already been investigated; the subtraction of the reduction constants then gave values for the real magnitudes.

The method possesses many advantages and, when applied with sufficient elaboration, apparently gives a scale of high precision. For example, suppose that a screen absorbing 6 mags. is used. Since standards between the tenth and fifteenth magnitudes are presupposed, bright stars between magnitudes 4 and 9 are within reach; and since in each case the same constant is subtracted from the magnitude of the reduced-intensity image, the slope of the resulting scale will be independent of any error affecting the constant. The process is, in effect, a transference of the adopted scale for the intermediate stars to the region of the brighter objects.

To provide the necessary checks, it is desirable that all possible arrangements of apertures, covering a wide range of reduction constants, should be used. There will thus be accumulated a number of separate, but overlapping, determinations of the scale, each of which should be homogeneous with that of the intermediate stars; their intercomparison controls the errors of the constants, and their mean is the final result. When the data are extensive, as is here assumed, the reductions can be modified so that the result is no longer dependent upon that for the intermediate stars.

To keep the labor within reasonable limits, this part of the investigation was restricted to the stars of the North Polar Sequence, the brightest of which is Polaris; but in order that there might be a satisfactory connection with the intermediate group, a number of the latter were reobserved by the bright-star method. These considerations led to the selection of 32 objects distributed between magnitudes 2.5 and 12.3, photographic. More or less complete series of observations were obtained with 10 different arrangements of the aperture, besides partial series for several others, the constants ranging from 1 to 11 mags. The overlapping scales, which are based upon 213 plates and 662 individual magnitudes, are in good agreement; not only are they sensibly parallel, but the constant systematic differences are small, which indicates that the reduction constants are well determined.

With the completion of the investigation of the bright stars, it became possible to reduce the entire series of results to the international

zero point. This was accomplished by making the mean brightness of the white stars near the sixth magnitude equal to the mean of their visual magnitudes in *Harvard Circular*, No. 170, proper allowance for spectrum being made for those objects not of type AO.

The resulting catalogue of photographic magnitudes includes 617 objects, the great majority of which are fainter than the tenth magnitude. All of the latter are close to the Pole of 1900, and among them are included the stars of the Polar Sequence. To these special attention has been given, although a large number of other stars have well determined magnitudes, based on ten or more individual values. The very faint objects, which are relatively numerous, are naturally subject to greater uncertainty.

The treatment of the data for the photovisual scale was exactly the same as that outlined above for the photographic scale. Although only 6 plates were used for the intermediate and faint stars, the precision is much greater than one would thus be led to expect. Owing to the better definition of the images on the isochromatic plates, the probable error of a photovisual magnitude is only two-thirds that of a photographic result. The photovisual scale for the bright stars, which depends upon 122 plates and 367 individual magnitudes, is probably quite as reliable as the photographic scale in the same region. Final photovisual magnitudes were obtained for 339 stars between magnitudes 2.1 and 17.5.

The average deviation of a single photographic magnitude, including the scale error of a plate over a range of 8 or 9 magnitudes is 0.125 mag.; the corresponding photovisual result is 0.087 mag.

About 300 stars have had both their photographic and photovisual magnitudes determined, and, in consequence, color indices for these are available. These confirm a result announced at an earlier stage of the work, namely, that the faint stars are all relatively red. For the bright stars, we have small, and even negative, color indices in large numbers. At the seventeenth photovisual magnitude the smallest value is 0.6 or 0.7 mag., the lower limit gradually increasing as the fainter stars are approached. This phenomenon is undoubtedly of very great significance, but its interpretation cannot at present be given with certainty. It is evident, however, that the determination of star colors will form an important part of stellar investigations in the future.

This last consideration only emphasizes the necessity of precision in the magnitude scales, for any relative error enters to its full amount into the color index, and thus vitiates the results of comparisons involving stars of different degrees of brightness. In the present case a supplementary investigation provided an important control.

Hertzsprung has determined by an entirely different method—that of effective wave-lengths—the colors of nearly 200 stars in the cluster N. G. C. 1647. These can be expressed as color indices and compared with similar results derived directly from photographic and photovisual magnitudes. The agreement or disagreement of the two series of values immediately checks the relative errors of the scales.

To execute this comparison, the polar scales were transferred to the region of the cluster by 10 plates of duplicate exposure—5 for each scale. All possible care was taken to avoid errors in the zero points, for uncertainties here also enter to their full amount into the color indices.

In this manner color values were obtained for about 50 stars between magnitudes 11 and 14.5, which had also been observed by Hertzsprung. There is some uncertainty involved in the transformation of the effective wave-lengths into color indices; but it is not likely that the mean difference in the two series of values exceeds a tenth of a magnitude, and there is some evidence that it is even less. The relative errors of the scales between the sixth magnitude, which defines the international zero point, and the thirteenth or fourteenth magnitude can therefore scarcely exceed this limit.

Comparisons of the individual scales for the Pole with the results of other observers are also important in their indications. The only other investigation covering the entire range of brightness is that of the photographic scale carried out at the Harvard Observatory. With proper allowance for color, the Harvard and Mount Wilson results are in close agreement, that is, the scales are parallel, from the tenth to the fifteenth magnitude. For the fainter stars there is a large divergence, which has arisen from differences in the method of reduction (the Harvard scale for the fainter stars is based upon Mount Wilson plates). For the bright stars there is also a divergence, amounting to about 6%, whose origin is not yet fully explained.

Other investigations of the photographic scale have been made at Greenwich and Potsdam. These extend from the ninth to the sixteenth or seventeenth magnitude; after correction for color to reduce to the system of the reflector, both show a close accordance with the Mount Wilson results. In addition, the bright stars between the fourth and eighth magnitudes have been observed at Göttingen and at the Yerkes Observatory. These results are also in close agreement with the Mount Wilson scale.

The material for the photovisual scale is less abundant. Visual magnitudes of the Polar Sequence stars have been determined at Har-

vard as far as the fourteenth magnitude. This scale intersects the Mount Wilson photovisual scale at the sixth and the twelfth magnitudes, but at other points there are important differences, some of which are obviously due to color. Further, the *Yerkes Actinometry* contains photovisual magnitudes as far as 7.5. The Mount Wilson results agree satisfactorily with these, and there is also good accordance with the visual magnitudes of Müller and Kempf. Beyond this no results have as yet been published, although others are in preparation. A detailed comparison with all these various investigations will be included in forthcoming papers in the *Astrophysical Journal*,[4] which will also give fuller details and a summary of the numerical results for the Mount Wilson scales. The complete discussion will appear as Volume 3 of *Papers of the Mount Wilson Solar Observatory*.[5]

[1] *Mt. Wilson Contr.* No. 80; *Astrophys. J.*, 39, 307 (1914).
[2] *Ibid; Mt. Wilson Contr.* No. 70; *Astrophys. J.*, 38, 241 (1913).
[3] *Potsdam Publ.* No. 67.
[4] *Mt. Wilson Contr.* Nos. 97, 98, 102; *Astrophys. J.* (In press.)
[5] *Publications of the Carnegie Institution of Washington.*

MITOSIS IN TRICHOMONAS

By Charles Atwood Kofoid and Olive Swezy
ZOOLOGICAL LABORATORY, UNIVERSITY OF CALIFORNIA
Presented to the Academy, March 16, 1915

The process of cell-division in the simpler Protozoa is significant in its relation to the evolution of nuclear and extra-nuclear structures. The behavior of the extra-nuclear organelles in unicellular organisms during the process of binary fission is significant as to the origin and relationships of such structures as flagella, blepharoplast, and axostyle. One of the distinctions between the Ciliata and the Flagellata has been held to be the direction of the plane of division, transverse in the former, longitudinal in the latter; therefore all reported cases of transverse division in Flagellata should be critically inspected.

Observations on mitosis in *Trichomonas augusta*, a flagellate parasitic in the digestive tract of amphibians (*Diemyctylus torosus Rana boylei*, and *Bufo halophilus* from California, and *Rana pipiens* from Chicago) enable us to make a fuller correlation of mitosis in the Flagellata with that in the Metazoa, to correct or supplement the observations of others regarding mitosis in trichomonad flagellates, and to establish on ample morphological grounds the essentially longitudinal nature of their division. Our conclusions have been verified in all essential features, in

eleven species of seven genera parasitic in vertebrates. The conclusions are based on hundreds of preparations made by the wet Schaudinn iron-haematoxylin, or by the Giemsa method, and controlled by observations on living forms in sealed culture slides, or on mixed pure cultures in sterilized media.

The vegetative phase of *Trichomonas augusta* (fig. 1) presents an elongated pyriform body with a hyaline axial rod, the axostyle (*ax.*), enlarged anteriorly and projecting posteriorly in a sharp point. A pale spheroidal nucleus (*n.*) lies in the anterior end. It contains one or more deeply staining karyosomes and a faint chromatin network.

The spheroidal deeply staining blepharoplast (*bl.*, figs. 1–3) lies close to the anterior surface attached to the anterior end of the axostyle. From it pass anteriorly the three long lightly staining anterior flagella (*ant. fl.*), and posteriorly the undulating membrane (*und. m.*) consisting of a waving protoplasmic film in whose margin lies a deeply staining chromatic thread or margin (*chr. m.*), and at whose base is a heavier basal chromatic rod (*bas. chr. r.*). Posteriorly the two chromatic structures unite at the point of emergence in the lightly staining posterior flagellum (*post. fl.*).

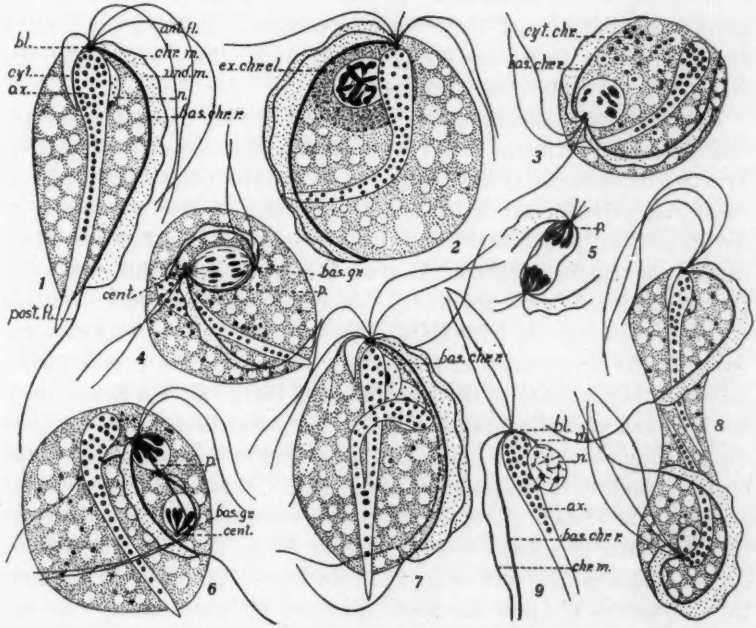
From the blepharoplast the axostyle (*ax.*), a large hyaline club-shaped flexible and mobile structure, passes posteriorly in an axial position. It is enlarged anteriorly near the nucleus and contains a varying number of fairly uniform axostylar chromidia (*ax. chr.*). In macerated specimens (fig. 9) the nucleus is seen to be attached to the head of the axostyle by a persistent and but slightly chromatic strand or rhizoplast (*rh.*). These extra-nuclear structures together with the nucleus survive as a coherent unit the maceration of the surrounding cytoplasm.

The prophase of the process of mitosis is initiated in rather large, somewhat spheroidal individuals (fig. 2), by the apparent splitting of the wavy chromatic margin of the undulating membrane distally from the blepharoplast. At the same time the homogeneous intra-nuclear chromidial cloud, which diffusely fills the nucleus as mitosis approaches, emerges from it and forms the extra-nuclear cloud (*ex. chr. cl.*), a diffusely staining halo about the nucleus, in which minute chromidia soon appear (fig. 2), spread into the surrounding cytoplasm, and increase in the axostyle throughout its length.

As the nucleus clears up there emerges in it a distinct (fig. 2), often clearly continuous chromatin skein, which speedily breaks up, finally into five chromatin masses, or chromosomes, each of which splits longitudinally into two chromosomes (fig. 3) within the intact nuclear membrane, prior to any arrangement in an equatorial plate. There are

differences in these chromosomes observable in most, if not all, of the mitotic figures (figs. 3–6). There are two of medium size, one large one, and two small ones, one of which lags (fig. 4) in the metaphase. After splitting the sister chromosomes swing into an end-to-end position (figs. 3, 4) as they move into the equatorial plate.

The blepharoplast has in the meantime (fig. 3) divided into two, to



Mitosis in *Trichomonas augusta* Alexeieff. × 1500; *ant. fl.*, anterior flagella; *ax.*, axostyle; *ax. chr.*, axostylar chromidia; *bas. chr. r.*, basal chromatic rod; *bas. gr.*, basal granule; *bl.*, blepharoplast; *cent.*, centrosome; *chr. m.*, chromatic margin; *cyt.*, cytostome; *cyt. gr.*, cytoplasmic granule; *ex. chr. cl.*, extra-nuclear chromidial cloud; *n.*, nucleus; *p.*, paradesmose; *post. fl.*, posterior flagellum; *rh.*, rhizoplast; *und. m.*, undulating membrane.

Fig. 1. Active motile form prior to division.

Fig. 2. Prophase, with chromatin skein, split border and sprouting flagellum.

Fig. 3. Later prophase with five pairs of split chromosomes.

Fig. 4. Late metaphase with blepharoplasts at poles, each divided into centrosome and basal granule.

Fig. 5. Late anaphase with blepharoplast not divided.

Fig. 6. Early telophase. Nuclei still connected by paradesmose.

Fig. 7. Late telophase. Paradesmose seen end to end and therefore foreshortened, axostyle splitting.

Fig. 8. Mitosis completed, cytoplasmic division approaching.

Fig. 9. Nucleus and extra-nuclear motor apparatus after maceration.

one of which are attached two of the anterior flagella, while the other takes the remaining one and a new anterior flagellum which grows out from the blepharoplast. We have not found the blepharoplast to consist of four basal granules at the roots of the flagella as indicated by Martin and Robertson[3] for *Trichomonas gallinarum*.

The new chromatic basal rod grows out from the blepharoplast (figs. 3, 6), apparently independently of the old, as a new structure in the membrane below one of the chromatic marginal filaments (fig. 3) and distally extends in a new posterior flagellum, thus completing the division of the undulating membrane.

The metaphase is approximated in figure 4 in which, however, the nuclear membrane remains intact, as in fact it does throughout mitosis. The two blepharoplasts have migrated to the two poles of the pointed ellipsoidal nucleus, and each has divided into a centrosome (*cent.*), at the apex of the spindle, and the adjacent basal granule (*bas. gr.*) to which the flagella remain attached. In some instances (fig. 5) this division of the blepharoplast is not apparent. No astral rays are evident. Within the nuclear membrane faint spindle fibres connect the parting chromosomes to the centrosomes at the poles. Connecting the two blepharoplasts as they migrate to the polar position (figs. 3–6) is a heavy chromatic thread which lies *outside* of the nuclear membrane. This we name the paradesmose, though in origin it may seem to be homologous to the central spindle of the metazoan mitotic figure. It is this structure which according to Dobell[1] gives rise to the new axostyles of the daughter cells. It later disappears (fig. 7) without giving rise to any structures. As the split chromosomes swing in to the equatorial plate they assume the end-to-end position like that described by Montgomery[5] for the spermatocytes of *Euschistus*. Spindle fibres play no part in their splitting. Slight inequality in an "x"-"y" relation between the daughter chromosomes is generally evident in the case of the large chromosome. There is no evidence, however, that any of the divisions here described are maturation divisions, or that their end-to-end position is a telosynapsis.

The anaphase is accomplished by the movement of the chromosomes to the poles of the spindle into contact with the polar centrosomes and by the constriction of the nucleus into a dumbbell shape (figs. 5–6).

The telophase (fig. 6) results from the final constriction and separation of the daughter nuclei which immediately assume a spheroidal form and move apart drawing out the paradesmose between their basal granules. This is perfectly distinct as an extra-nuclear chromatic thread joining the two blepharoplasts or the two basal granules after each blepharoplast parts into centrosome and basal granule (figs. 4–6). The parades-

mose later fades out after the karyosomes and chromatin network reappear within the daughter nuclei (fig. 7).

At the close of the telophase (fig. 7) division of the axostyle proceeds by longitudinal splitting from the anterior end posteriorly. There is a suggestion that axostylar chromidia are also divided, at least in the distal region (fig. 7). Actual division of individual chromidia has not been seen though in some dividing axostyles (fig. 7) their relative dimensions in parent and daughter axostyles strongly suggest their division. The numbers of chromidia vary so that they do not afford critical evidence for use on this point.

The proofs of division of the axostyle in our material are ample though their detection requires well-prepared slides and persistent search. Dobell[1] and Prowazek[2] describe the origin of these axostyles from the "centrodesmose" and the former concludes that it is therefore the homologue of the central spindle, and Doflein in his recent *Lehrbucher der Protozoenkunde* accepts this origin. This strand throughout all our material is everywhere extra-nuclear and we therefore propose for it the name paradesmose since it cannot occupy the position of the central spindle or "centrodesmose." Kuczynski[4] has shown that Dobell's and Prowazek's conclusions are invalid since the paradesmose persists *till after the new axostyles appear*. This author, however, falls into the error of concluding that the daughter axostyles arise as new outgrowths from certain end granules of the old axostyle originally connected with the blepharoplast. He finds that the old axostyle fades out and the daughter axostyles arise as new outgrowths. In our material it has always been possible to detect in all individuals which have passed the anaphase of mitosis one of three conditions, either (1) the single undivided axostyle or (2) this axostyle in process of splitting longitudinally, or (3) two complete daughter axostyles. The presence of the axostylar chromidia has been of great assistance in following the longitudinal splitting of this organ in *Trichomonas augusta*. A similar splitting of the axostyle occurs in *Lamblia muris* and in two or more species of *Hexamitus*.

Wenyon[6] states that the axostyle of *Trichomonas intestinalis* of the mouse divides longitudinally after the division of the nucleus and blepharoplast. His figure, however, does not support his statement. It shows two axostyles rather than a dividing one.

Shortly after the axostyle splits the two nuclei and axostyles move farther apart, the body elongates, the anterior ends of the two daughters come to lie at opposite poles (fig. 7) and the cytoplasmic central bridge progressively narrows down until the two daughter organisms separate. The final plane of constriction is transverse to the main axis of each cell and of the common elongating mass.

An inspection of our figures and still more of our preparations reveals a great variety of positions of the organelles of the cell. Observations on living cells under high magnifications in culture slides convince us that this variability in position is normal and not due to artefacts.

These conditions have led Martin and Robertson[3] to state that division in *Trichomonas gallinarum* may occur in any one of three planes and that "these divisions may be termed respectively longitudinal, transverse, and oblique."

During the period of mitosis the body is somewhat rounded up, and is constantly in more or less violent motion. In these activities not only the flagella and undulating membranes share but also the axostyle. This bends at right angles (fig. 2), curves (fig. 6), and twists about very energetically almost as a flagellum lashing about in the viscid cytoplasm. Its activity is accompanied by a considerable mobility of the cytoplasm with the result that the positions of the organelles, of the nuclei, of the blepharoplasts with their accompanying flagella and undulating membrane, and even of the axostyle itself, are subject to incessant readjustments in their relations. They may even become somewhat widely detached from one another (figs. 4–7). These conditions which Martin and Robertson[3] have interpreted as indicating other types of division than longitudinal are thus due to the protean activity of the organisms. When, however, we seek to define the plane of division on morphological grounds and accept the premitotic cell (fig. 1) as indicating the normal orientation of the organelles within the body, we find that, if the daughter blepharoplasts migrate equally 90°, as they normally do in mitosis, the nucleus of *Trichomonas* would be divided in a plane which in the premitotic arrangement is approximately longitudinal. The chromatic margin of the undulating membrane, the membrane itself, and the axostyle all split lengthwise, that is, longitudinally. *On morphological grounds the division of this flagellate is therefore solely longitudinal.* The interpretation of any other plane rests purely on variable and temporary positions of organelles which become movable during the *later phases* of mitosis.

This process of division has been interpreted, with emphasis, in *Trichomonas gallinarum* by these same investigators[3] as purely amitotic. The differences between their figures and our own are not very great, and it is quite possible that under certain pathological conditions nuclear appearances simulating amitosis may occur. We are inclined to the view that division in this species also is mitotic and that Martin and Robertson's[3] figures are not wholly incompatible with this interpretation. A division in which chromatin masses (chromosomes) of definite number and regular forms are differentiated, split longitudinally, and

move to the poles of a spindle at each of which a centrosome formed by the division and polar migration of the parent organelle is found, is essentially mitotic rather than amitotic.

The conclusions drawn are:

(1) Cell division in trichomonad flagellates is a true mitosis with differentiated chromosomes (five in *Trichomonas augusta*), which split longitudinally prior to their location in the equatorial plate.

(2) The nuclear membrane persists throughout mitosis. The blepharoplast which is connected to the flagella, rhizoplast, chromatic margin and basal rod of the undulating membrane, and to the axostyle, after division usually gives rise by division to a polar centrosome and an adjacent basal granule which alone retains connection with the extranuclear apparatus including the paradesmose. These two fuse again to form the daughter blepharoplasts.

(3) The paradesmose between the migrating blepharoplasts is extranuclear at all times, disappears after nuclear division, and does not give rise to the axostyle. Since this connecting strand lies outside of the nuclear membrane and connects basal granules and not centrosomes, it should not be called centrodesmose or central spindle, but rather the paradesmose.

(4) The axostyle splits longitudinally and thus forms the two daughter axostyles. These do not grow out as new structures in *Trichomonas augusta*. It and the chromatic basal rod (homologous with the parabasal chromatic structures of Janicki[7]) may be regarded as derivatives of the blepharoplast, homologous with flagella but intra-cytoplasmic.

[1] Dobell, C. C., Researches on the intestinal Protozoa of frogs and toads. *Q. J. Microsc. Sci., London*, **53**, 201–277, pls. 2–5 (1908).

[2] Prowazek, S., Untersuchungen über einige parasitische Flagellaten. *Arb. Gesundhtsamt., Berlin*, **21**, 1–41, pls. 1–4 (1904).

[3] Martin, C. H. and Robertson, M., Further observations on the caecal parasites of fowls. Part I. *Q. J. Microsc. Sci., London*, **57**, 53–81, pls. 10–14 (1911).

[4] Kuczynski, M. H., Untersuchungen an Trichomonaden. *Arch. Prot.*, **33**, 119–204, pls. 11–16 (1914).

[5] Montgomery, T. H., The spermatogenesis of an hemipteron. *J. Morph., Boston*, **22**, 731–815, pls. 1–5 (1911).

[6] Wenyon, C. M., Observations on Protozoa in the intestine of mice. *Arch. Prot.*, Suppl. v. **1**, 169–201, pls. 10–12 (1907).

[7] Janicki, C., Bemerkungen zum Kernteilungsvorgang bei Flagellaten namentlich bei parasitischen Formen. *Verh. Nat. Ges. Basel*, **23**, 82–111, 8 figs. (1912).

REPORT OF THE ANNUAL MEETING

Prepared by the Home Secretary

The Annual Meeting of the Academy was held in the Oak Room of the Raleigh Hotel and in the National Museum at Washington, D. C., on April 19, 20, and 21, 1915.

Sixty-one members were present, as follows: Messrs. Abel, Becker, Bell, Boltwood, Britton, Bumstead, Cattell, Chamberlin, Chittenden, W. B. Clark, F. W. Clarke, J. M. Clarke, Conklin, Coulter, Cross, Dall, Davenport, Davis, Day, Donaldson, Fewkes, Frost, Hague, Hale, Harper, Harrison, Hayford, Hillebrand, Holmes, Howell, Jennings, Loeb, Mall, Meltzer, Mendel, Merriam, Michelson, Moore, Morgan, Morley, E. L. Nichols, A. A. Noyes, W. A. Noyes, H. F. Osborn, T. B. Osborne, Parker, Pickering, Pirsson, Ransome, Reid, Remsen, Schuchert, Scott, Erwin F. Smith, Walcott, Webster, Welch, Wheeler, White, R. W. Wood, Woodward.

BUSINESS SESSIONS

The President announced that the preparation of Biographical Memoirs of deceased members had been assigned as follows:

Memoir of	*Assigned to*
Bowditch, Henry P.	Cannon, Walter B.
Gould, Benjamin Apthorp	Comstock, George C.
Mitchell, Henry	Hayford, John F.
Mitchell, Silas Weir	Welch, William H.
Chandler, Seth Carlo	Elkin, William L.
Peirce, Benjamin Osgood	Hall, Edwin H.
Holden, Edward Singleton	Campbell, William W.
Hill, George William	Brown, E. W.
Peirce, Charles Sanders	Cattell, J. McKeen.
Gill, Theodore Nicholas	Dall, William H.
Minot, Charles Sedgwick	Donaldson, Henry H.
Billings, John S.	Garrison, Fielding H.

REPORTS FROM OFFICERS OF THE ACADEMY

The reports of the President and of the Treasurer for 1914 as transmitted to the Senate of the United States by the President of the Academy were presented in their printed form and approved.

The report of the Home Secretary was presented as follows:

The President of the National Academy of Sciences.

Sir: I have the honor to present the annual report of the home secretary of the National Academy of Sciences for the year ending April 21, 1915.

Of the Scientific Memoirs of the National Academy of Sciences, volume 12, part 1, bearing the title, "Monograph of the Bombycine Moths of North America," by A. S. Packard, edited by T. D. A. Cockerell, has been published and distributed to the members, foreign associates, institutions, and reference libraries. Volume 12, part 3, of the Memoirs, entitled,

"The Turquoise," by Joseph E. Pogue, has also been published and distributed to the members. Part 2 of this same volume entitled, "Variations and Ecological Distribution of the Snails of the Genus Io," by Charles C. Adams, has received final consideration, and is now waiting to be bound at the Government Printing Office. The memoir forming volume 13, being "A Catalogue of the Meteorites of North America," by Oliver C. Farrington, only awaits press-work and binding before it is issued.

The biographical memoirs of John Wesley Powell, Charles A. Schott, and Miers Fisher Longstreth have been published. The publication of the memoir of J. Peter Lesley, by William M. Davis, has been approved by the committee on publications; and the biography of Henry Morton, by Edward L. Nichols, has been printed and awaits the portrait.

Three members have died since the last annual meeting: Theodore Nicholas Gill, on September 25, 1914, elected in 1873; Charles Sedgwick Minot, on November 19, 1914, elected in 1897; and Henry Lord Wheeler, on October 30, 1914, elected in 1909.

Of our foreign associates, Edward Suess, elected in 1898, died on April 26, 1914; August Weismann, elected in 1913, on November 5, 1914; Hugo Kronecker, elected in 1901, on June 6, 1914; G. F. J. Arthur Auwers, elected in 1883, on January 24, 1915.

There are 134 active members on the membership list, 1 honorary member, and 43 foreign associates.

Respectfully submitted, ARTHUR L. DAY, Home Secretary.

REPORTS FROM COMMITTEES ON TRUST FUNDS

A report was received from the directors of the Bache Fund, stating that the vacancy caused by the death of Charles S. Minot had been filled by the election by the two remaining members of the Board of Ross G. Harrison, and that he has accepted the appointment. The Board elected Mr. Ira Remsen as its Chairman. The report contained also an announcement of the research grants made from the Bache Fund during the year ending April 19, 1915.

A report was received from the Trustees of the Watson Fund, signed by E. C. Pickering (chairman), W. L. Elkin, and E. B. Frost. The report stated that the wish expressed in the will of the late James Craig Watson that tables be prepared of the motions of all the planets discovered by him has now been carried out in a most satisfactory manner by Mr. A. O. Leuschner, so that the income which has been used for this purpose during the last fourteen years is now available for the promotion of Astronomical Science in other directions. In the report the trustees recommended that the sum of five hundred dollars from the income of the Watson Fund be appropriated to John A. Miller, Director of the Sproul Observatory, for measuring plates already taken for the determination of stellar parallaxes; and that the sum of three hundred dollars be appropriated from the income of the Watson Fund to John E. Mellish, to enable him to undertake observations at the Yerkes Observatory. It was recommended that the Watson Medal and the sum of one hundred dollars be awared to Armin Otto Leuschner of the University of California for the skill and ability which he has shown in supervising the preparation of tables of the Watson asteroids, involving original methods, and leading to results of much value to celestial mechanics. These recommendations were adopted by the Academy.

A report was received from the Committee on the Henry Draper Fund, signed by George E. Hale (chairman). The Committee recommended the approval of a grant from the Draper Fund of $500 to W. W. Campbell, Director of the Lick Observatory, for the purchase and construction of spectrographic and other apparatus for use with the Crossley Reflector. The Committee also recommended the approval of a grant of two hundred and fifty dollars to S. A. Mitchell, Director of the Leander McCormick Observatory, for the purchase of a machine for measuring astronomical photographs. These recommendations were adopted by the Academy.

A report was received from the Committee on the J. Lawrence Smith Fund, signed by Edward W. Morley (chairman). The report described the progress made on certain researches which have received aid from the Fund. It was announced that, in accordance with the vote passed by the Academy in 1912, the fourth $250 installment of the grant of one thousand dollars has been paid to C. C. Trowbridge, of Columbia University, in aid of his study of the luminous trains of meteors. The Committee recommended a grant of five hundred dollars to S. A. Mitchell of the University of Virginia in aid of computations of orbits of meteors. The Committee also recommended that the meteorites remaining from the purchases made by George P. Merrill, Curator in the Department of Geology in the United States National Museum, under the grants awarded to him in aid of the study of certain elements suspected to be present in small quantities in meteorites, be deposited by the Academy in the United States National Museum. These recommendations were adopted by the Academy.

A report was received from the Directors of the Wolcott Gibbs Fund, signed by C. L. Jackson (chairman), describing three grants made from the fund during the preceding year and outlining the progress made on the researches aided by those grants.

A summarized statement of the grants made from the various trust-funds of the Academy during the year ending April 15, 1915 will be found at the end of this number of the PROCEEDINGS.

REPORTS FROM STANDING COMMITTEES

A report was received from the Committee on Solar Research, signed by George E. Hale (chairman) calling the attention of the Academy to the publication of volume 4 of the *Transactions of the International Union for Cooperation in Solar Research*, which contains the complete proceedings of the last meeting in Bonn, reports of the various committees, resolutions adopted by the Union, and several scientific papers on solar and stellar phenomena. The report states that the four volumes of *Transactions* already published by the Solar Union may be obtained from Longmans, Green & Company, New York City, at $2.50 per volume.

A report was received from the Editorial Board of the PROCEEDINGS, signed by Arthur A. Noyes (chairman), as follows:

The Editorial Board of the PROCEEDINGS reports to the Academy that four numbers of the PROCEEDINGS have now been issued containing sixty-nine original papers in addition to the report of the Autumn Meeting, notices of scientific memoirs, and announcements. These numbers have consisted of 258 pages, an average of 64 pages per number and of about four pages per article. The papers are distributed among different sciences as follows: mathematics, 11; astronomy, 11; physics, none; chemistry, 13; geology, 2; paleontology, 1; botany, 4; zoology, 5; genetics, 5; bacteriology, 2; physiology, 8; pathology, none; anthropology, 5; psychology, 2. It will be noticed that the subjects of physics, of geology and paleontology, and of pathology, have been very inadequately represented; and the Editorial Board urges members of the Academy in these fields to endeavor to remedy this situation.

An edition of 3000 copies of these four numbers has been printed. Of this edition about 900 are to be sent abroad to the libraries of universities and other active research institutions upon a mailing list prepared with great care by the Foreign Secretary aided by members of the Editorial Board. Of this edition 1200 copies have also been distributed in this country by the Home Secretary to important libraries and to the thousand persons whose names are starred in Cattell's *American Men of Science.*

A report was received from the Committee on the Collection of Historical Portraits, Manuscripts, and Instruments, signed by Charles D. Walcott (chairman). The committee announced in this report that the collection of portraits of members of the Academy has been brought together and arranged alphabetically; that the foreign secretary has turned over to the Committee the medal from the Groningen Academy celebrating its four hundredth anniversary; and that many photographs and certain pieces of apparatus have been presented by Mrs. Henry Draper and have been deposited in the United States National Museum.

GENERAL BUSINESS

Upon recommendation of the Council it was voted to accept the bequest of Mrs. Mary Anna Palmer Draper provided for by the following paragraph of her will: "I give and bequeath to the National Academy of Sciences, Smithsonian Institution, Washington, D. C., the sum of twenty-five thousand dollars ($25,000)."

The President announced that an invitation had been received from the members of the Academy living in New York City to hold the Autumn Meeting there, and that this invitation had been accepted.

REVISION OF THE CONSTITUTION AND RULES

The draft of the Constitution as amended and adopted in Committee of the Whole at the Chicago Meeting was presented for final action and adopted by the Academy on April 21, 1915.

This Constitution is printed on pages 30–37 of the *Report of the Academy for the Year 1914*, in such a way as to show clearly the new amendments. The most important of these provides that 15 (instead of 10) new members may be elected annually until the total membership of the Academy shall reach 250 (instead of 150). Another amendment provides that "the Academy

shall be divided by the Council into sections" (heretofore called standing committees) "representing the principal branches of scientific research;" and that "each section shall elect its own chairman" (heretofore appointed by the President), "who shall serve for three years." Another amendment provides that the annual meeting shall begin on the third Monday (instead of the third Tuesday) in April.

An amended code of rules was presented by the Committee on the Constitution and Rules; and this was adopted by the Academy on April 21, 1915. Minor and formal changes are thereby made in many of the former rules of the Academy. The new rules and those which have been substantially modified are as follows:

III. 5. A standing committee of three members called the Program Committee, a local committee of five members appointed for each meeting, and the Home Secretary, shall together constitute the Committee of Arrangements, of which the Home Secretary shall be chairman.

The term of service of the Program Committee shall be three years, one member retiring annually, the chairman to be designated by the President.

It shall be the duty of the Program Committee to prepare the scientific program for the Annual Meeting and for this purpose it shall be empowered to solicit papers from members or others. It shall also be empowered to ascertain the length of time required for reading papers to be presented at the scientific sessions of the Academy, and, when it appears advisable, to limit the time to be occupied in their presentation or discussion.

The local committee shall meet not less than two months previous to each meeting. It shall prepare the detailed program of each day, and in general shall have charge of all business and scientific arrangements for the meeting for which it is appointed except those specifically assigned to the Program Committee in the case of the Annual Meeting.

IV. 1. Each section of the Academy shall elect a chairman to serve for a term of three years. If the chairmanship of a section becomes vacant in an interval between stated meetings of the Academy the President shall appoint a chairman to serve until the next stated meeting, at which time the section shall elect a chairman for a term of three years.

IV. 2. The chairman of each section of the Academy shall submit to the members of his section, not later than November 1 of each year, a ballot containing the names of all those persons who received not less than two votes in the nominating ballot of the preceding year and of any other persons who were newly proposed for consideration at that time. Each member of the section shall be expected to return this ballot to the chairman within two weeks with his signature and with crosses placed against the names of those persons whom he is prepared to endorse for nomination. Each member may also write upon the ballot in a place provided for the purpose any new names which he desires to have included in the ballot to be submitted to the section in the following year. The vote resulting from this ballot shall be regarded as informal.

The chairman shall then submit to the members of his section a new ballot showing the results of the informal vote; and each member shall be expected to return this ballot to the chairman with his signature and with crosses placed against the names of those whom he will endorse for nomination.

The chairman shall then certify to the Home Secretary, prior to January 1, the names of those persons who have been voted for on this second ballot by a majority of the members of the section, and shall furnish him a list of the publications of these nominees, as required by the Constitution.

IV. 4. Preference ballots for election of members shall be sealed in a blank envelope which shall be inclosed in another bearing the name of the sender and which shall be ad-

dressed to the Home Secretary. Such envelopes shall be opened only by the tellers. If in any case the tellers are unable to determine who cast a ballot, or if the latter contains more names than are to be voted for, the ballot shall be rejected; but minor defects in a ballot shall be disregarded when the intent of the voter is obvious.

V. 1. The publication of the PROCEEDINGS shall be under the general charge of the Council, which shall have final jurisdiction upon all questions of policy relating thereto. The preparation of the PROCEEDINGS for publication shall be entrusted to an Editorial Board. This board shall consist of a chairman and a managing editor, both of whom shall be appointed by the Council for definite terms of service; of the Home Secretary and Foreign Secretary, ex officiis; and of a body of associate editors representing the various branches of science which are to be included in the scope of the PROCEEDINGS. The managing editor, who may be a non-member of the Academy, shall receive a salary which shall be fixed by the Council. It shall be the duty of the managing editor to prepare the PROCEEDINGS in detail for publication; but the chairman of the Editorial Board shall decide, in consultation with the managing editor, in regard to the acceptance, rejection, or substantial modification of papers offered for publication. The associate editors shall be appointed by the Council, upon recommendation of the chairman of the Editorial Board, for a period of three years, one-third of them retiring annually. The Home Secretary and the Foreign Secretary shall be responsible for the distribution of the PROCEEDINGS in their respective fields.

VI. 5. The standing committee on finance shall consist of the Treasurer ex officio as chairman and two members to be appointed annually by the President.

ELECTION OF COUNCILLORS AND OF NEW MEMBERS

J. M. COULTER and W. H. HOWELL were elected members of the Council for a period of three years, to succeed W. T. Councilman and R. S. Woodward, whose terms of service had expired.

The following persons were elected as new members of the Academy:

HENRY SEELY WHITE, Mathematician, Vassar College, Poughkeepsie, N. Y.
CHARLES GREELEY ABBOT, Astrophysicist, Astrophysical Observatory, Smithsonian Institution, Washington, D. C.
ROBERT ANDREWS MILLIKAN, Physicist, University of Chicago, Chicago, Ill.
ALEXANDER SMITH, Chemist, Columbia University, New York City.
SAMUEL WENDELL WILLISTON, Paleontologist, University of Chicago, Chicago, Ill.
WILLIAM ERNEST CASTLE, Zoologist, Harvard University, Cambridge, Mass.
FRANK RATTRAY LILLIE, Zoologist, University of Chicago, Chicago, Ill.
GRAHAM LUSK, Physiologist, Cornell University Medical College, New York City.
VICTOR CLARENCE VAUGHAN, Pathologist, University of Michigan, Ann Arbor, Mich.
GRANVILLE STANLEY HALL, Psychologist, Clark University, Worcester, Mass.

SCIENTIFIC SESSIONS

Two public lectures on the WILLIAM ELLERY HALE FOUNDATION were given on April 19 and 21 by THOMAS CHROWDER CHAMBERLIN, of the University of Chicago, on the Evolution of the Earth.

A public illustrated lecture was given by GEORGE H. PARKER, Official Representative of the Academy upon the Special Commission appointed by the President of the United States to study and report upon the Alaskan Fur Seals during the summer of 1914, on The Fur Seal Herd of the Pribilof Islands.

Three public scientific sessions were held on April 19 and 20 at which the following papers were presented:

THOMAS H. MORGAN: Localization of the hereditary material in germ cells.

JACQUES LOEB: Stimulation of growth.

LAFAYETTE B. MENDEL: Specific chemical aspects of growth.

EUGENE F. DU BOIS, Medical Director, Russell Sage Institute of Pathology (by invitation of the Program Committee): Basal metabolism during the period of growth.

I. S. KLEINER and S. J. MELTZER: Retention in the circulation of injected dextrose in depancreatized animals and the effect of an intravenous injection of an emulsion of pancreas upon this retention.

JOEL STEBBINS, Draper Medallist: The electrical photometry of stars.

GEORGE E. HALE: A vortex hypothesis of sun spots.

EDWIN B. FROST: The spectroscopic binary, Mu Orionis.

ROBERT W. WOOD: One-dimensional gases and the experimental determination of the law of reflection for gas molecules.

ROBERT W. WOOD: The relations between resonance and absorption spectra.

EDWARD L. NICHOLS and H. L. HOWES: On the polarized fluorescence of ammonio-uranyl chloride.

ROBERT A. MILLIKAN (by invitation of the Program Committee): Atomism in modern physics.

WILLIAM MORRIS DAVIS: Problems associated with the origin of coral reefs, suggested by a Shaler Memorial study of the reefs of Fiji, New Caledonia, Loyalty Islands, New Hebrides, Queensland, and the Society Islands, in 1914.

F. W. CLARKE: Inorganic constituents of marine invertebrates.

HENRY FAIRFIELD OSBORN and J. HOWARD MCGREGOR: Human races of the Old Stone Age of Europe, the geologic time of their appearance, their racial and anatomical characters.

CHARLES A. DAVIS, Geologist, Bureau of Mines (by invitation of the Program Committee): On the fossil algae of the petroleum-yielding shales of the Green River Formation.

NATHANIEL L. BRITTON: The forests of Porto Rico.

J. WALTER FEWKES: Pictures on prehistoric pottery from the Mimbres Valley in New Mexico and their relation to those of Casas Grandes.

CHARLES B. DAVENPORT: Inheritance of temperament.

CHARLES B. DAVENPORT: Inheritance of Huntington's chorea.

AWARD OF THE HENRY DRAPER MEDAL

At the Annual Dinner of the Academy held at the Hotel Raleigh on April 20, 1915, the Henry Draper Medal was awarded to Joel Stebbins, of the University of Illinois, in recognition of his work on the Application of the Selenium Cell to Stellar Photometry.

RESEARCH GRANTS FROM THE TRUST FUNDS OF THE ACADEMY

During the twelve months preceding the Annual Meeting of the Academy the following grants for the promotion of research were made from trust funds of the Academy.

GRANTS FROM THE BACHE FUND

No. 182, W. C. KENDALL, $600. April 30, 1914. For illustrations in color and incidental expenses in connection with part II (Salmonidae) of Fishes of New England to be published by the Boston Society of Natural History.

No. 183, C. G. ABBOT, Smithsonian Institution, $250. June 29, 1914. To complete and test on Mt. Wilson in California an apparatus consisting of a concave cylindrical mirror of about 100 sq. ft. surface adapted to heat oil to circulate through a reservoir containing ovens and water pipes, and thereby to utilize solar radiation for cooking and for heating water for domestic purposes.

No. 184, P. W. BRIDGMAN, Harvard University, $500. September 14, 1914. To continue the work on high pressures, especially to investigate the phase changes brought about in various substances by very high pressure.

No. 185, ROBERT W. HEGNER, $160. December 26, 1914. To determine the visible changes that take place during the differentiation of the germ cells in the embryos of hermaphroditic animals, and to discover, if possible, the cause of these changes.

No. 186, J. VOÛTE, $800. February 9, 1915. For the determination of parallaxes of Southern Stars by transits, to be conducted at the Royal Observatory, Cape of Good Hope, wholly at the expense of Mr. Voûte, except for these grants. (A grant of $1000 was previously made for the same purpose.)

No. 187, H. H. LANE, $500. April 14, 1915. For a comparative study of the embryos and young of various mammals, in order to determine, by physiological experimentation and morphological observations, the correlation between structure and function in the development of the special senses.

GRANT FROM THE J. LAWRENCE SMITH FUND

No. 4, C. C. TROWBRIDGE, Columbia University, $250. In aid of his study of the luminous trains of meteors.

GRANTS FROM THE WOLCOTT GIBBS FUND

No. 3, W. J. HALE, University of Michigan, $100. May 15, 1914. For assistance in a research on derivatives of 2.3-diacetyl pentadiene.

No. 4, W. D. HARKINS, University of Chicago, $200. November 25, 1914. For a special potentiometer and galvanometer to study cobaltamines and ternary systems of fused salts.

No. 5, MARY E. HOLMES, Mt. Holyoke College, $100 (second grant), March 18, 1915. For her research on the electrolytic determination of cadmium.

GRANT FROM THE WATSON FUND

No. 9, A. O. LEUSCHNER, University of California, $960. April 21, 1914. For the preparation of tables of the Watson asteroids.

GRANT FROM THE DRAPER FUND

C. G. ABBOT, Astrophysical Observatory of the Smithsonian Institution, $500. April 21, 1914. For the services of a computer for the reduction of observations of the solar-radiation and the absorption of the sun's atmosphere.

The following additional grants were authorized by the Academy at the business session of April 19, 1915.

GRANTS FROM THE WATSON FUND

No. 10, JOHN A. MILLER, Sproul Observatory, Swarthmore College, $500. For the measurement of plates already taken for the determination of stellar parallaxes.

No. 11, JOHN E. MELLISH. To enable him to undertake observations at the Yerkes Observatory.

GRANTS FROM THE DRAPER FUND

W. W. CAMPBELL, Lick Observatory, University of California, $500. For the purchase and construction of photographic and other apparatus for use with the Crossley Reflector.

S. A. MITCHELL, Leander McCormick Observatory, University of Virginia, $250. For the purchase of a machine for measuring astronomical photographs.

GRANT FROM THE J. LAWRENCE SMITH FUND

No. 5, S. A. MITCHELL, University of Virginia, $500. For computation of the orbits of meteors.